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FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. LXX. AUGUST, 1875. No. 2.

EDITORIAL.

ITEMS AND NOVELTIES.

Steel in Engineering Practice—During the session of the American Railway Master Mechanic Association, in New York, last May, some experiments were tried to show the comparative strength of cast steel and wrought iron car axles. The experiments appear to have been conducted under the supervision of a committee appointed by the Association, the steel axles having been furnished by the Midvale Steel Works of this city, and the iron axles selected by two members of the Association who desired the test. One lot of iron axles having been forged expressly for the test, at the shops of the gentleman furnishing them. The other lot having been selected by the other gentleman, from the axles used successfully on the road under his charge. A full account of these experiments appeared in the June No. of *The American Artisan* of New York, one of the editors of that paper having been present during the test, and an abstract of the report of the committee was published in the *Railroad Gazette*, of New York. These accounts have been pretty generally copied into other journals, and the experiments have been mostly received as use-

ful and corroborative of the commonly conceived idea of the superior strength of steel. These experiments consisted in letting fall a drop weight of 1600 lbs. from heights of 25 and 35 feet upon the bars of iron and steel which rested on rigid supports placed 3 feet apart, the blow being delivered midway between the supports. While some iron axles stood three or broke at the fourth blow, others broke at the second blow, all of 25 feet fall; and the only steel axle that was broken at all, had three blows of 25 feet and then eight blows from the height of 35 feet.

It may be well to state that the experiments tried in New York were merely a repetition or an exposition of the test adopted by railroads using steel rails in determining the fitness of the steel for railroad purposes. On the reasonable assumption that car axles are submitted to strains requiring stiffness and strength, the test of dropping a weight upon the axle and noting the deflection seems one that would naturally be resorted to. It has, therefore, come to be common practice in ordering steel axles that for one hundred axles ordered, a certain number agreed upon in addition shall be furnished —that this additional number, selected at random from the pile, shall be subjected to the following test: they are placed one at a time upon rigid supports, 3 feet apart; upon the centre of the axle, midway between the supports, a drop weight of 1500 lbs., raised 25 feet, is allowed to fall that distance. The amount of bending caused by the blow is noted. The axle is turned over and another blow from the same height is given, which straightens the axle more or less, so turning the axle between each blow, five blows are given. If all the test-axles stand these blows, the whole lot is accepted; if any of them break, they are all rejected. It is usual to continue the test by blows of 1500 lbs., drop falling 40 feet, until the axles are broken, but all blows after the first five are not considered in the test, so far as the acceptance of the axle is concerned. The trial of the sample axles is supposed to show two things: great strength to resist strains or shocks, and in relation to the amount of bending, the hardness or stiffness of the material. We have seen steel axles break on the second blow, and we have seen them so tough as to require many 40 feet blows to break them. We cannot but think the test the best one possible, under the circumstances.

It has been our intention to comment on these experiments, but we delayed doing so to obtain some definite information from prominent

railroads as to the success of the steel axles in actual use. While engaged in this inquiry, we are met by an article in one of our exchanges, a widely circulated paper, devoted to the iron interest. The article is headed "Steel Railway Axles." After commenting on the nature of the test, the writer says: "If tests made by means of weights subjected an axle to strains in any respect similar to those it encounters in actual service, the results might be considered as conclusive; but they do not; consequently, they are practically valueless as determining whether steel is, or is not, a better material than iron for this use." Again: "It (steel) has from time to time been tried on railroads, and each time abandoned." Then the writer gives his conceptions of the reasons for this, and further on says: "Steel axles have been placed under cars on several different railroads, by gentlemen with whom we are acquainted, and in each case they were abandoned on account of their liability to heat. We know this as a fact, although we do not know the reason for it." These few sentences suggest a treatment of the subject not originally intended. That steel car axles should have been tried and then abandoned, is not surprising, as the cost of steel is even now very much greater than the cost of iron. But that their use should have been abandoned on account of steel being more liable to heat, is a matter of great surprise, and worthy of careful consideration. An inquiry of the leading engineers other than railroad engineers, fails to elicit any experience that would seem to confirm this statement. All that we have heard about steel being liable to heat comes to us in statements somewhat like the article above referred to. That is to say, a mere assertion without any explanations of the conditions under which the trial had been made.

We are told by the writer before alluded to, that a certain size of journal is needed for purposes of lubrication, and that the Master Car-Builders' standard axle has journals $3\frac{3}{4}$ inches diameter, while $3\frac{1}{8}$ inches journals are carrying the load with probably a large margin of strength, but with too little surface for lubrication. Friction being independent of surface within certain limits, the $3\frac{1}{8}$ inches journal in iron, if 5 inches long, may heat, if 6 or 7 inches long may, with its lateral increase of surface, bear the load with safety from heating, and no more frictional resistance, because the diameter, and consequently the surface velocity, has not been increased. Does it not seem reasonable, that with some stronger and stiffer material than iron, the journal may be made to present to

its brass box the amount of surface needed to prevent abrasion in a less diameter and a greater length?

There really seems no reason why the practice of the railroads should differ materially from the practice of the workshop. Car axles revolve under conditions not much worse than the journals and shafts in many machines, and what applies to one applies as much to the other. Any journal, if submitted to too much pressure, will heat. When it does heat from causes other than want of proper lubrication, it is necessary to diminish the load to diminish velocity or to extend the surface under pressure, and in the case of journal, all the things being equal, this extension can best be made useful by extension in length, not in diameter. In an over-hanging journal, as the outside bearing of car axles, an enlargement of diameter increases velocity of the rubbing surfaces, and so increases the frictional resistance inasmuch as the same frictional resistance is acting at a greater distance from the centre. An increase of length, the diameter remaining the same, will diminish the wear without increasing the frictional resistance, inasmuch as the pressure per square inch of surface will be less. When the limit of extension has been reached in such journals on iron shafts of a given strength, no engineer would hesitate to make them still longer if a stronger and stiffer material can be substituted for the iron.

At the same session of the Master Mechanics' Convention at which the steel axles were tested, the form of iron axle recommended by the Master Car-Builders, with a journal $3\frac{3}{4}$ inches diameter, 7 inches long, was not adopted on account of its being larger and heavier than axles doing good service, and on the minds of some who voted, on account of the probable introduction of *steel* axles of a much smaller size than could with safety be made of iron. While some roads, as we are told, have tried and abandoned steel car axles, we know that others have used them, and are using them successfully after a continuous experience of many years.

We have made inquiry of one railroad using steel axles extensively, and found that it alone has nearly twenty-six thousand steel axles in use under its passenger and some freight cars.

It may be asked why roads so using them do not take advantage of the extra strength and stiffness, and reduce the size of the axles, to diminish the dead weight, to diminish the cost, and to diminish the frictional resistance?

We hope soon to be able to present to the readers of this JOURNAL a statement of the experience of this railroad now using 26,000 axles, when it will be seen that that road does use as long a journal, and one of smaller size, than that recommended by the Master Car-Builders' Association, and use it to advantage—made of steel.

That other railroads using steel axles should not at once avail themselves of this advantage of steel, is clear enough to those familiar with the management of roads. Changes in such matters as size of axles involve great changes in many other portions of the cars. Such changes cannot be made at once; a wise policy retains existing sizes, but insures security to passengers by the one of the stronger material in the equipment of passenger cars, and then slowly and surely makes any changes that may seem warranted by experience, not of one year, or two years, but of many years, and as indicated by the clear record of all that experience.

Inasmuch as the steel interests of this country are now so rapidly increasing, we deem an inquiry into its possible displacement of iron in engineering practice of great importance.

We have been informed that steel is entering more and more largely into the construction of locomotives abroad, and if we mistake not, the engines made for a Russian railway last year by the Grant Locomotive Works, of Patterson, N. J., had all parts that could be, made of steel. The rapid advance of the steel manufacture in this country, and the cheapening of the material by improved methods of manufacture, demand a careful consideration of its merits in machine construction.

Steel is now procurable of different qualities, suited to different uses to which it may be applied, and we think the time is near at hand when these qualities will be so well defined as to render their selection by the engineer an easy matter. All the so-called steels, from the finest tool steel down to the qualities which contain so little carbon as to prevent them from showing any hardening properties when heated, and cooled suddenly, seem to have physical properties which readily distinguish them from what we know as bar or wrought iron. The process of manufacture of the low grades of steel is so distinct from the mode of making the wrought iron of commerce, that the so-called steel, containing the least possible amount of carbon, differs materially from the so-called wrought iron which

has been proved to contain the greatest amount of carbon. This difference is marked in regard to strength and stiffness. Steel of all grades, from the softest up to the hardest, behaves differently in the lathe from wrought iron, presenting a more uniform surface when turned or planed, and seldom showing any sign of seam or fiber, as is evidenced in wrought iron.

This finer surface, the greater strength, the greater stiffness, seem to indicate it as *par excellence* the material for machine construction. On railroads steel rails are taking the place of iron, steel tires are encircling the driving wheels, steel sheets form the boilers, and steel connecting rods of light model are in some cases taking the place of the more cumbersome iron ones; but yet we are told that steel car axles are more liable to heat than iron ones.

We have heard the same statement made of steel crank-pins; we have, therefore, included them in our inquiries of railroads using them, and we look for the report now being prepared for us with interest. In machine shop practice we found examples of steel crank-shafts succeeding where iron shafts failed.

As an illustration of this displacement of iron by steel, in engineering practice, mention may be made of the experience of a firm in this city. Some small engines were being constructed, intended to be run at high speed, 900 revolutions per minute. They were fitted with wrought iron crank shafts, carefully fitted to run in phosphor-bronze bearings. In the first trial of one of these engines, the shaft cut so badly as to stop the engine long before the proper speed had been obtained. The shaft was taken out, smoothed up, and the bearing carefully lapped out, to give more room for oil, and under an unusual lubrication, it again cut. A case-hardened iron shaft was tried with slightly different result. Steel was then used, and the same size steel shaft ran without cutting and showed, after long use, no unusual wear. The steel used was that known as machinery steel, and was adopted in place of iron only on account of its being stiffer. A careful examination of the conditions under which the soft iron and the case-hardened iron gave out, clearly indicated that the shaft bent in the journal under the pressure of the work on the crank.

In machine shop practice, iron shafts are used on account of their cheapness wherever practicable, but when it is deemed advisable not to increase the diameter, on account of the velocity, or for other rea-

sons, steel is always resorted to as permitting greater strains, so that in considering the proportions of machines, it is common usage, in case of doubt as to strength of shafts, to substitute steel for iron.

S.

The Commission on Water Supply, to which we referred in our last number, have devoted their time and attention ever since to the examination and study of the important matters entrusted to them. The survey for the conduit line from the proposed Perkiomen Reservoir, to the East Park Reservoir, has been made to a point on the Wissahickon, whence to the East Park Reservoir the topography having been previously obtained, the general character of the route is known. The distance on a final line would be about 34 miles, which is much longer than the distance originally contemplated. While the local obstacles along the route to the construction of this conduit line may not be more formidable than had been formerly anticipated, its increased length will of course add to its cost. The estimates of its cost we learn have not yet been completed.

The survey for the proposed conduit line from a point opposite New Hope, high enough to bring the water by gravity from a reservoir in that vicinity, to a convenient city distributing reservoir, has been begun, and is now in progress.

These surveys are made under the direction and supervision of members of the Commission. Measurements of the actual pumping at Fairmount Works have been made on several occasions by members of the commission, assisted by other experts; the results of which will appear in their report.

The subject of the pollution of rivers, by sewage, etc., and especially in its bearing upon the water supply from the Schuylkill and Delaware rivers, is receiving particular attention. A number of analyses of water from various points have already been made and reported, and others are still in process of investigation.

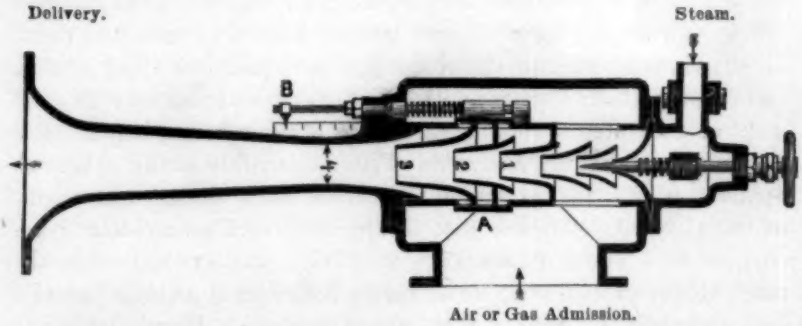
Purity is the first consideration; abundant supply, although of vast importance, must be secondary. There seems to be no question, however, that the City of Philadelphia has at her command, for the future, an ample supply of the purest water; but it is important to ascertain the best plan for introducing and maintaining it. It is to be presumed that the gentlemen having the matter in charge will overlook nothing that may be essential to a correct judgment upon a matter of such vital consequences to the City of Philadelphia.

Kœrting's Jet Apparatus.—The invention of M. Giffard's injector, and the success attending its introduction, suggested at once the application of its principles to other purposes. Out of it, besides a host of rival "injectors," have grown the "ejectors" and "ejector condensers" of various makers. Prominent among the workers in this field, appears the name of Mr. E. Kœrting, of Hanover, who has of late directed his attention to the utilization of induced currents as a means of transmitting motion and power; some of this gentleman's very successful applications of the steam jet are exceedingly interesting and well worth the careful attention of engineers. These various devices of Mr. Kœrting appear to supply a want long felt, and to have proved a paying investment for the inventor.

Our attention has recently been directed to this subject by Messrs. Schütte & Gœhring, of this city, who, we understand, are the licensees of Mr. Kœrting in this country, and who have made some modifications in his inventions, adapting them to American use. We have had an opportunity to see in operation one of Mr. Kœrting's "Forge Blowers." In this case a jet of steam of about $\frac{1}{32}$ of an inch in diameter puts in motion a column of air of, let us say, 10 lbs. pressure. This induced current of air, mixed with the steam which set it in motion and by which it was warmed, passes into and through the inducing nozzle of a second apparatus where it increases its volume by additional air. The volume of air discharged from the first blower and used as an inducing current in the second blower, is conveyed to it through a receptacle constructed as a cooler, in such a way that the air which is drawn in by the second blower is also made to pass through this receptacle, side by side with the mixture of air and steam, thus taking up some heat, condensing the steam, contained in the primary blast, and in this way forming a condenser and heat regenerator at the same time, so that the heat of the small amount of steam employed at first is used in warming the blast, while the blast is freed from moisture, which might be detrimental in obtaining welding heats. The apparatus we saw in use was placed in an establishment where a forge was needed, and which was not accessible to the blast pipes that supplied wind to the other forge fires. The exceeding convenience of this little blower operated by, seemingly, so small a quantity of steam, was very noteworthy. We understand the American licensees contemplate some change in the form of the "Jet Forge Blower," and we may at some future time illustrate it.

We now present a cut of Mr. Kœrting's "gas exhauster," for the purpose of keeping the pressure off of the retorts, or a slight pressure or vacuum on the retorts as may be required. This instrument illustrates the principle applied to all of the Kœrting devices for forcing or exhausting air or gas.

The inducing current in this case is a steam-jet, the quantity of which is controlled by a spindle in the steam nozzle; and the induced current is formed in a series of nozzles of increasing area. The purpose of these nozzles is to regulate the admission and proper mixture of the inducing and induced currents in such proportions as not to lose power by sudden shocks. In the particular use to which this instrument is applied, as in many other cases, the quantity of delivery must be variable, while all the other conditions remain the same. Thus, supposing the difference of gas consumption in winter and summer to be, say four to one, in each case the counter pressure of the washers, purifiers, etc., remains the same. To overcome a certain pressure, the induced current must have a certain speed, depending on the specific gravity of the liquid or fluid, so that to reduce the quantity of delivery working against the same pressure, the size of the instrument must be reduced, *i. e.*, the area of the last mixing nozzle must be reduced. This is accomplished in the following manner:



The inlets to the last three mixing nozzles are closed by a slide, A, so that in the positions of the slide, as shown in the cut, the last admission of gas is through nozzle 1, which in this case, constitutes the size of the instrument, and the gas admitted up to 1 is from there discharged through the remaining nozzles, the same as if they were a continuation of the diverging tube. By forcing the slide towards

the delivery end of the instrument so as to admit gas successively through 2, 3, and 4 by uncovering the inlets into these nozzles, the capacity can be increased correspondingly to the areas of their nozzles, all other conditions remaining the same, except a proportionate increase or decrease of steam admission by means of the spindle in the inducing steam nozzle. From experiments we have seen tried, great care is needed to have these various parts correctly proportioned, but when so proportioned the instrument is said to be economical, and to compare favorably with other efficient devices. It is claimed by the makers that the correct proportion is so imperative that instruments made of the same general size, but not correctly proportioned, have been found to require ten times the amount of steam for the accomplishment of the same purpose that a well-constructed apparatus needs.

Mr. Kœrting claims that for all purposes where a blast of air or other gas is needed, his instruments will be found economical and convenient; and that in producing and maintaining a vacuum, of say twenty-two inches of mercury, they have proved successful.

All jet apparatus work may be classed under the head of the mode of performing work by the continuous action of combined bulk and velocity. The principle has been quite fully illustrated in the various papers that have been written on the Giffard Injector for supplying steam boilers with water, so far as that instrument is concerned, and well-informed engineers are apt to speak of all kinds of jet apparatus as Giffard injectors. But a Giffard injector cannot be used to perform all the kinds of work to which the jet has been successfully applied in well-proportioned instruments. Thus, while the Giffard injector is admirably adapted to forcing water into a steam boiler, it presents a very uneconomical mode of merely lifting water into a tank. In each application of the jet of steam to perform work, the apparatus must of necessity be modified to suit the peculiar work required to be accomplished. The two examples given of the gas exhauster and the forge blower explain what we mean, in both Mr. Kœrting's arrangements of multiple nozzles, *i. e.*, of nozzles which take in the air or gas in succeeding spaces and succeeding nozzles, are used, but in one process there is no attempt to separate the steam from the gas, while in the other the steam is condensed, in inducing a second ingress of air, which enters the fire free from moisture. When the blowers, actuated by jets of steam, are used as under-grate blowers, the steam admitted with the air is a positive advantage, as the grate bars are

somewhat preserved, and the slight moisture seems to act advantageously on the fire which is required to yield its heat from the surface of the fire after the air has passed through it and combined with the burning fuel. In a forge-fire, or in a cupola, the heat is required to be used at the point where the air strikes the fuel and in the mass of the fuel—not from the surface of the fire. S.

Silver Coinage.—The Director of Mints, now on this coast busily preparing the mints in this city and Carson for an increased silver coinage, says, in a letter from Carson, dated July 16th: "The hydraulic presses and other machinery sent out here last year have been placed in position, and will do more than double the coinage capacity of the Carson mint, and it is estimated that with the necessary coinage of gold there can be coined half dollars and dimes. The supply of trade dollars will probably be sufficient until September 1st. In the meantime, I hope to be able to arrange for the coinage of divisionary silver coins at the two mints at San Francisco and Carson, at the rate of from $1,200,000 to $1,500,000 per month." It is estimated that the amount of fractional silver turned out from the coinage mints within the next six months will be at least $4,000,000.—*Mining and Scientific Press.*

Puddling with Natural Gas.—The following information regarding the use of natural gas in puddling iron at the works of Messrs. Rogers & Burchfield, Leechburg, is obtained from the *American Manufacturer*. These works, which have become so famous for the use of natural gas in the operations incident to rolling mill practice, are situated on the right bank of the Kiskiminitas, about six miles above its junction with the Allegheny River. There are five puddling furnaces, with two more building, six heating-furnaces, six trains of rolls, two steam-hammers, one refinery, two knobbling fires, two annealing-furnaces, and one "stack" for terne plates, and two building for tin-plates. All of the heat and power required for this mill is from gas, excepting, of course, the charcoal used. This gas comes from a well in a ravine on the opposite side of the river, which was sunk for oil, but produces only gas and a small portion of salt water.

* * * * * *

"In using the gas in the ordinary puddling-furnace, the only change made has been to brick up the bridge, the gas being fed to the fur-

nace through iron pipes, and the firing being done with a piece of lighted paper, the supply being regulated by an ordinary gate. The result is that the heat can be controlled at will without any more attention than the mere turning of a gate, and as fully a third of the labor at a puddling-furnace is keeping up the fire, this is no considerable item. * * * * * *

"The pipes conveying the blast are carried in at the top of the furnace, and strike the molten metal at an angle with the surface of somewhat over 90°. During the week, up to Friday noon, less than 500 pounds of ore had been used in feeding the furnace. No cinder was used when the iron began to boil, but the blast was put on, and the boiling was complete, the cinder in the iron flowing liquid. * * * * *

"The quality of the iron is somewhat wonderful. With the ordinary gray coke iron, sheets for tin-plates, equal to those from the best charcoal iron, are made at a cost of $50 per ton less. The knobbling fires are dispensed with, and all their iron made with the use of gas and blast. In a future issue we expect to give the results of some careful experiments."

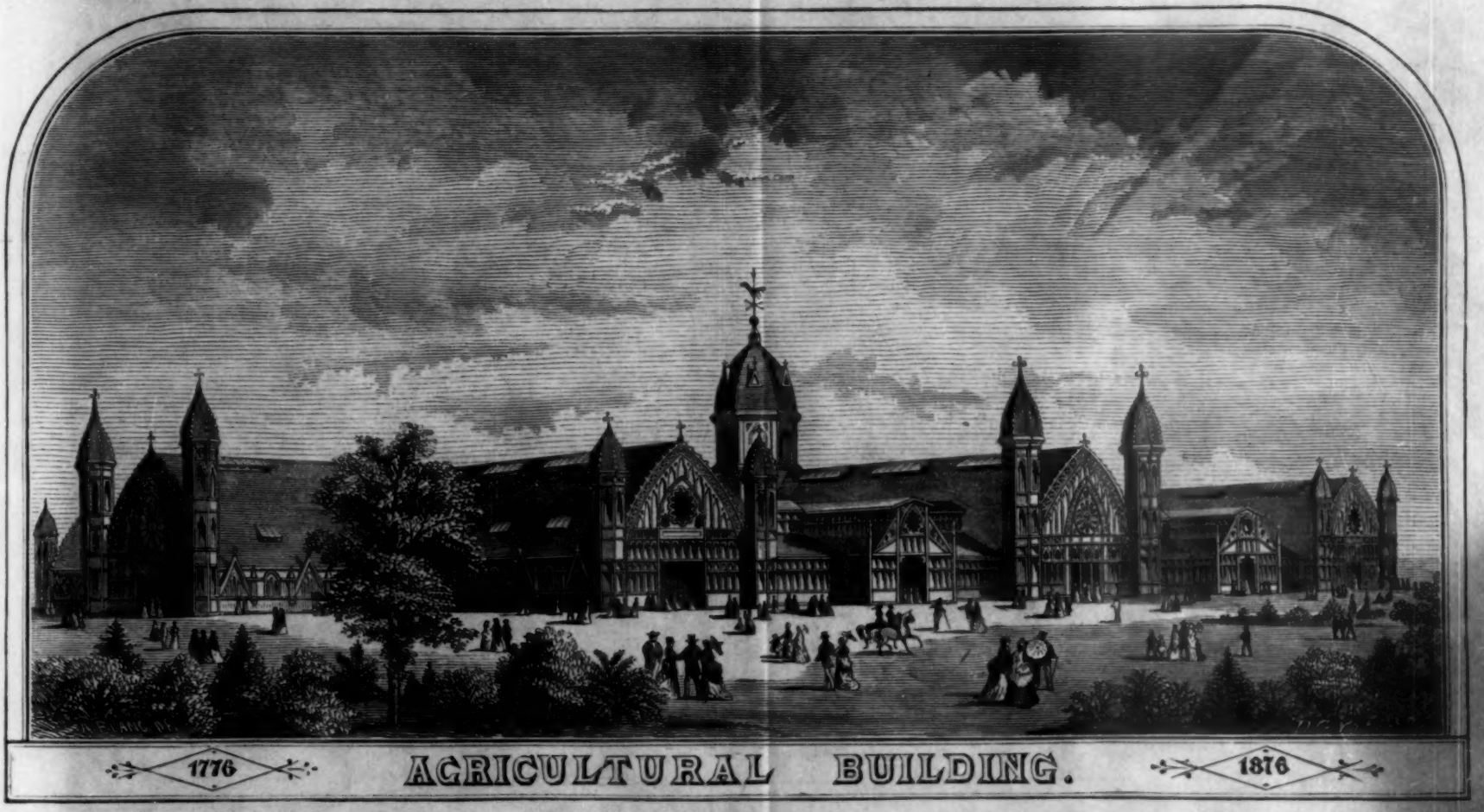
Centennial Exhibition.—The next in importance, after those already illustrated, is the Agricultural Building, which will stand north of Horticultural Hall, and east of Belmont Avenue.

The extreme dimensions of the building are 540 feet front by 800 feet in depth, consisting of a central nave 800 feet in depth by 100 feet in width, with a central transept 100 feet in width by 540 feet in depth, and two side transepts 80 feet in width by 540 feet in depth.

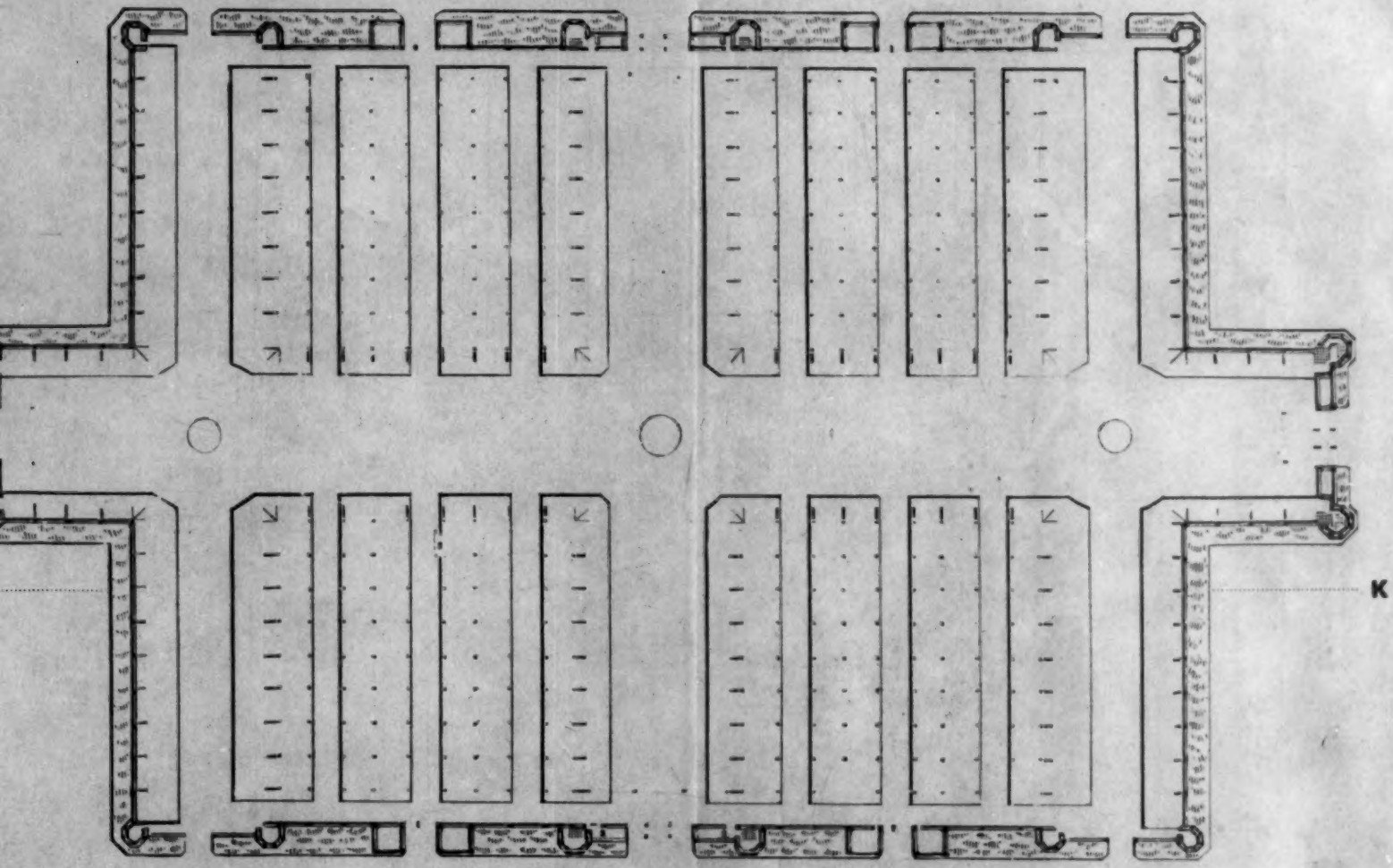
The construction of the nave and transept section is by Howe trusses, built curvilinear, and set to the form of two sides of an equilateral Gothic arch, springing from the ground line.

The principals are set to uniform spacings of 20 feet between centres, the depth of truss being 4 feet 6 inches for the 100 feet spans, and 3 feet 9 inches for the 80 feet spans.

At the intersection of the nave and central transept, the diagonal trusses are coupled, separated 8 feet by lattice bracing, at the foot being 10 feet in depth, converging to 6 feet at the base of dome and lantern. The intersection of lesser transepts with nave are propor-

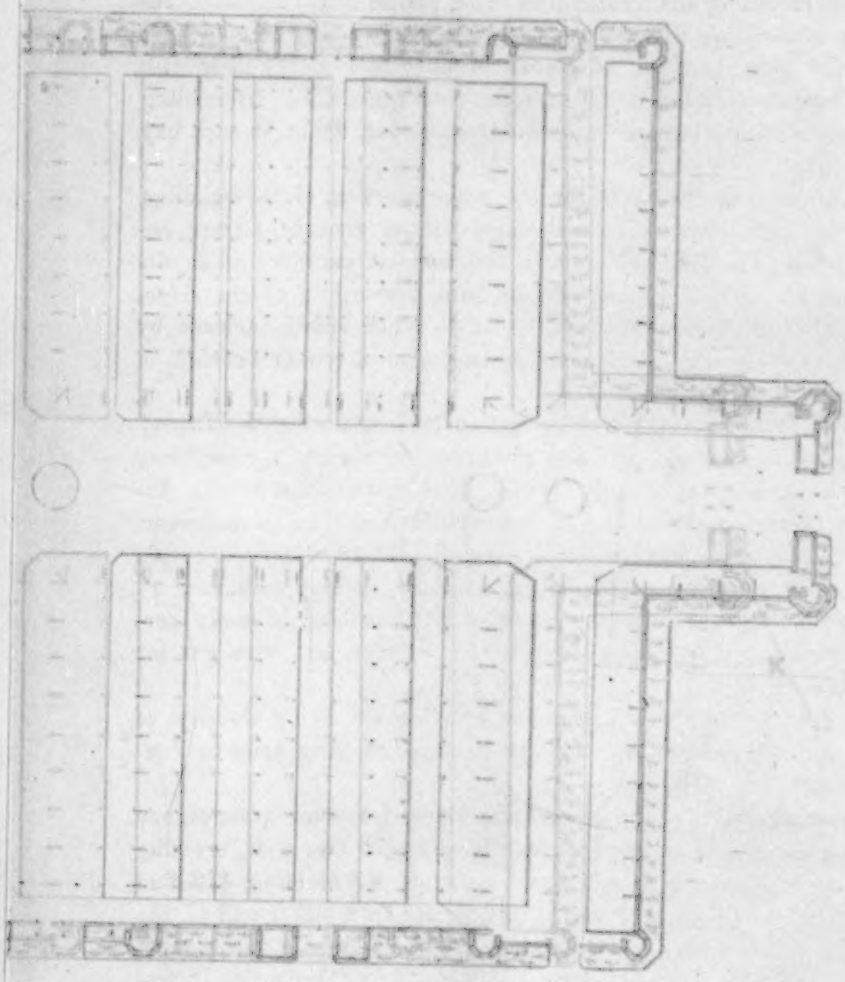


International Exhibition, Philadelphia, 1876.



Ground Plan of the Agricultural Building.

INTERNATIONAL EXHIBITION, PHILADELPHIA, 1876.



tionately less, but of similar construction. The intervening areas between the nave and transept sections are enclosed by simple shedding.

The entire structure will be built of timber left from the saw, to be finished upon interior surfaces by an alum sized color wash, only the exterior siding and frontal lines being planed for painting. The section of building formed by the arch trusses will receive light direct by glass sections, in planes forming roof cover, their stilt at the base constructed, as Louvres, for ventilation. The intervening shedding will have lantern lights continuous their depth, in each bay of 60 feet.

The truss system adopted for the major portion of the building, provides roof and wall construction in the one element, a truss, enclosing the extended floor area in the simplest manner; while the elevation of the roof section and its form, converging to the ridge, will lessen the effect of the sun's heat, to which space, enclosed by temporary roof cover, without the protection of a ceiling beneath, is subject in the summer season.

The object of this structure being to provide space for the display of agricultural machinery and products economically, simplicity of construction was sought, rather than embellishment of a finished structure. Within the Agricultural Hall will be steam power, and all necessary appliances for driving all such machinery as cotton gins, sugar presses, plantation mills, threshers, fanning mills, &c.

The building is drained by sewage beneath the floor, is amply provided with fire-plug stations within and without, and with gas for police surveillance.

The contract for the works was awarded to Mr. Philip Quigley, of Wilmington, Delaware, who engages to complete them prior to January 1st, 1876.

The arrangement of the ground plan shows four main avenues, one running north and south, 780 feet long by 70 feet wide, crossing which at right angles, is one at the centre of the building, 472 feet long by 60 feet wide, and one 25 feet distant from either end of the building, 472 feet long by 30 feet wide. The building is thus divided into four sections, each of which is subdivided by three aisles 18 feet wide, extending through it, and opening into the main north and south avenue at one end, and at the other end into side passages which extend along the east and west sides of the building.

The eastern half of the Main Exhibition Building has the roof on, is partly glazed, and much of the floor is laid. The western half of the frame is up, and the sheathing on the roof, and there still remains the frame of the transept to erect.

That portion of Machinery Hall east of the transept, including the tower, is completed, except a portion of the floor, and is painted and glazed. That west of the transept is erected, and most of the roof on, and the frame of the annex is up.

In the middle tower, at the east end of this building, will be placed an immense clock with two large dials, one showing outward, and the other inward, and twenty smaller dials will be placed along the length of the building inside, giving the correct time from the same machinery.

All the masonry of the Art Building is completed, except a portion of the two arcades; the roof is all on, and the figure on the top of the dome is in place.

The iron-work and masonry of Horticultural Hall are completed, and a portion of the roof on.

The foundations of the United States Government Exhibition Building are laid, and the work is making good progress. K.

Banked up for 217 Days.—The following letter from the Union Iron Works Company, of Cleveland, to the editor of the Pittsburgh *American Manufacturer*, shows remarkable success in an operation which, when long continued, is always a source of anxiety to the managers of blast furnaces.

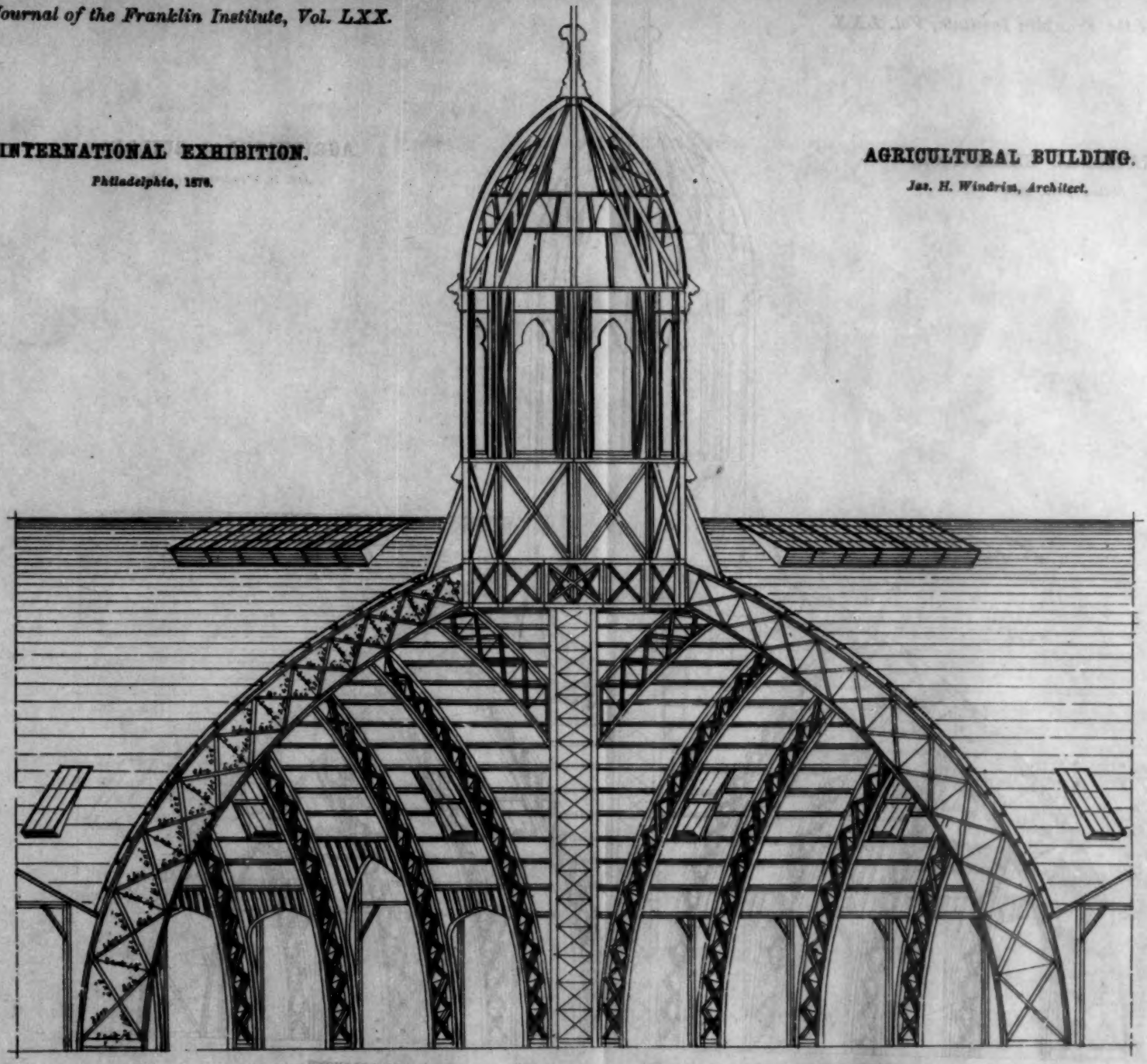
EDITOR AMERICAN MANUFACTURER:—In your items of "Manufacturing News" of a few issues since we noticed some items regarding the blowing in of a blast furnace at Phœnixville, Pa, that had been banked up some 110 days, saying, "If successful it would be a remarkable feat," and a few items after that stating it was *not* successful. Permit us to call your attention to the following facts regarding the "Emma Furnace," owned and operated by this Company, which we think will be of interest to furnacemen and your readers generally. This furnace stood banked up from December 4, 1874, until the 9th inst. (July, 1875), being seven months and five days or equal to 217 days, without blast or draft, and this too during the most severe winter known for a long time. Standing this length of time holding her *fire* intact without chilling or cracking, or any unfavorable results, is, we think, a

INTERNATIONAL EXHIBITION.

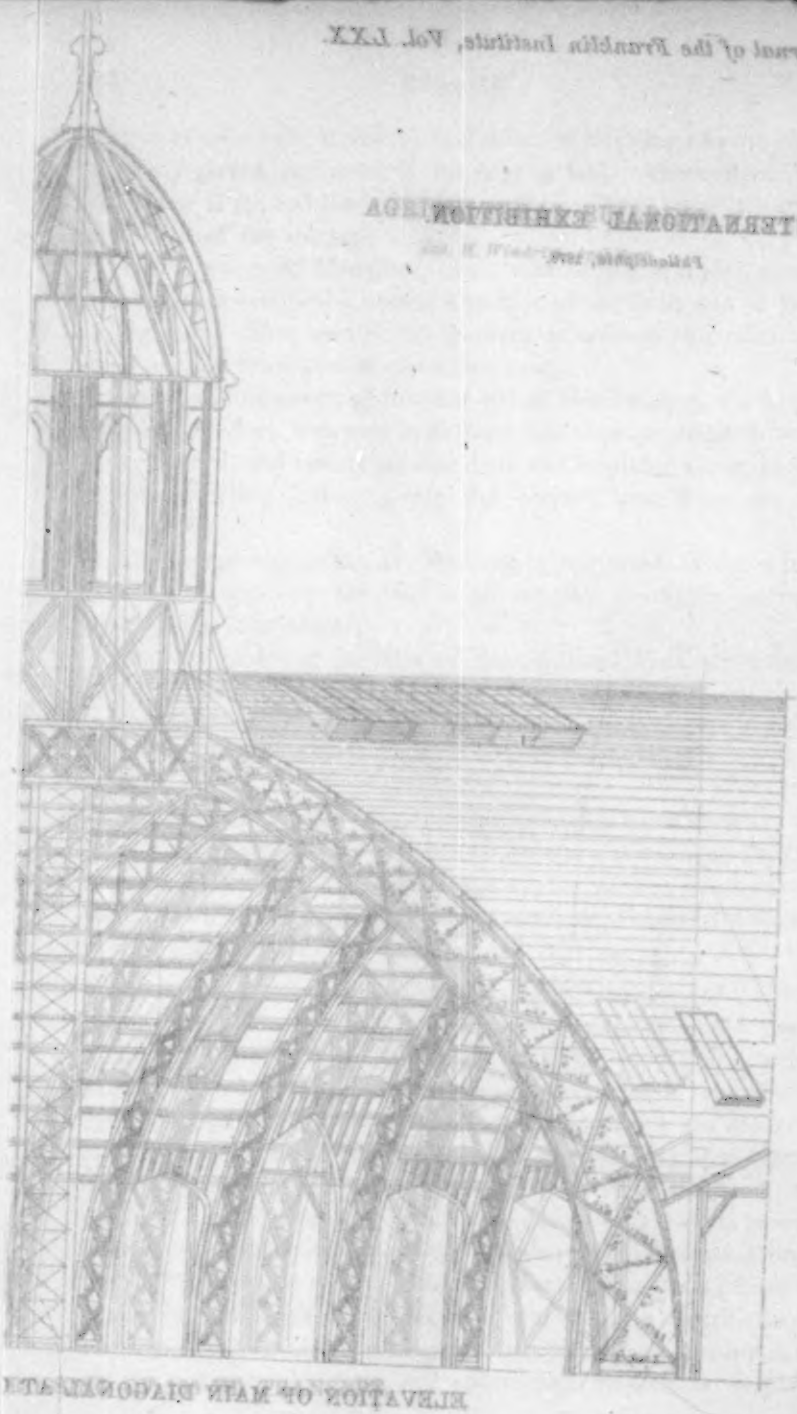
Philadelphia, 1876.

AGRICULTURAL BUILDING.

Jas. H. Windrim, Architect.

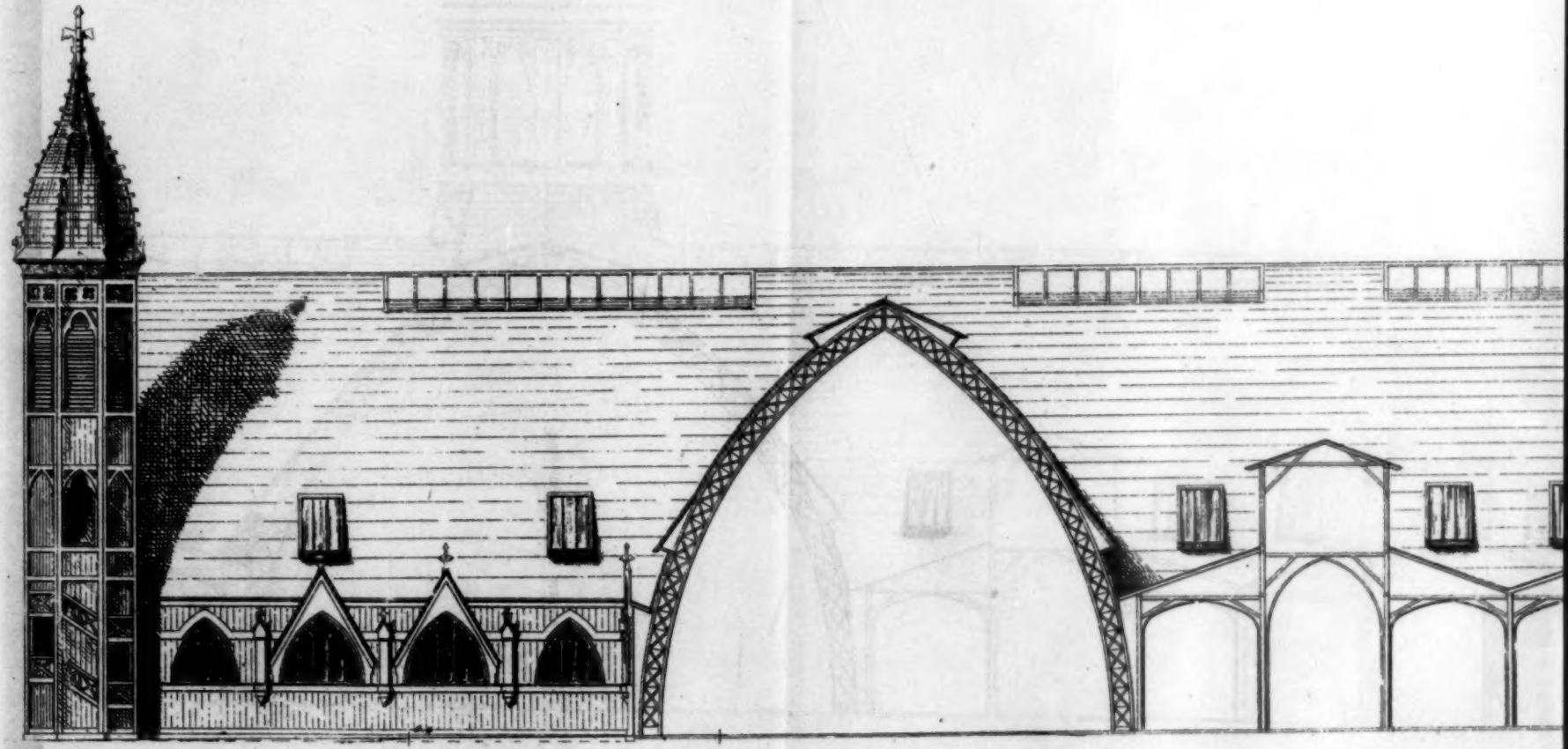


ELEVATION OF MAIN DIAGONAL AT CROSSING OF 100 FT. TRANSEPT.

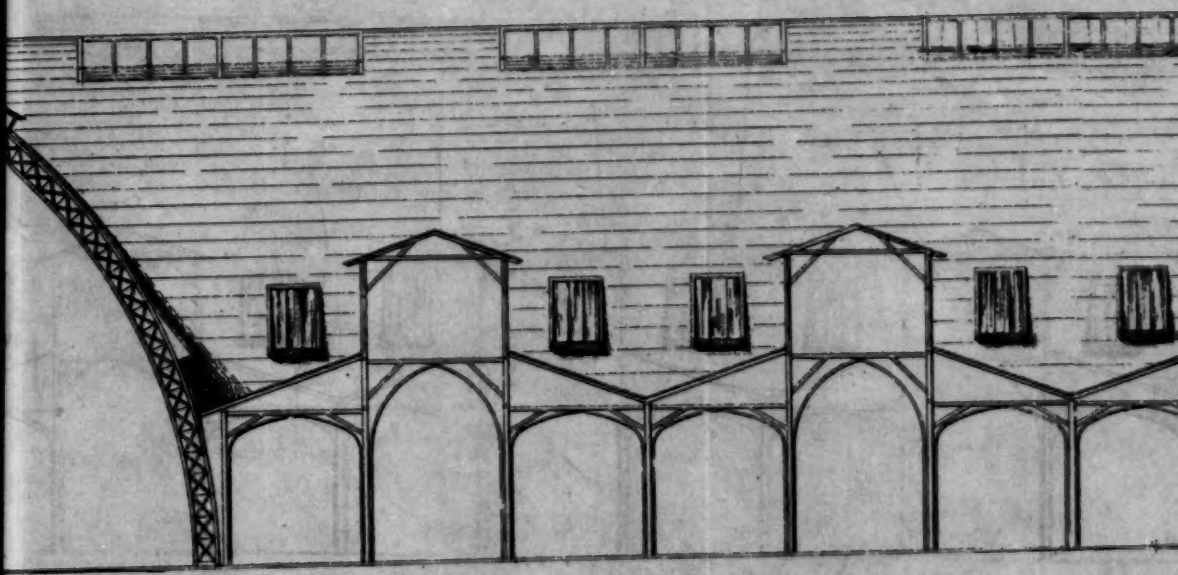


INTERNATIONAL EXHIBITION.

Philadelphia, 1876.



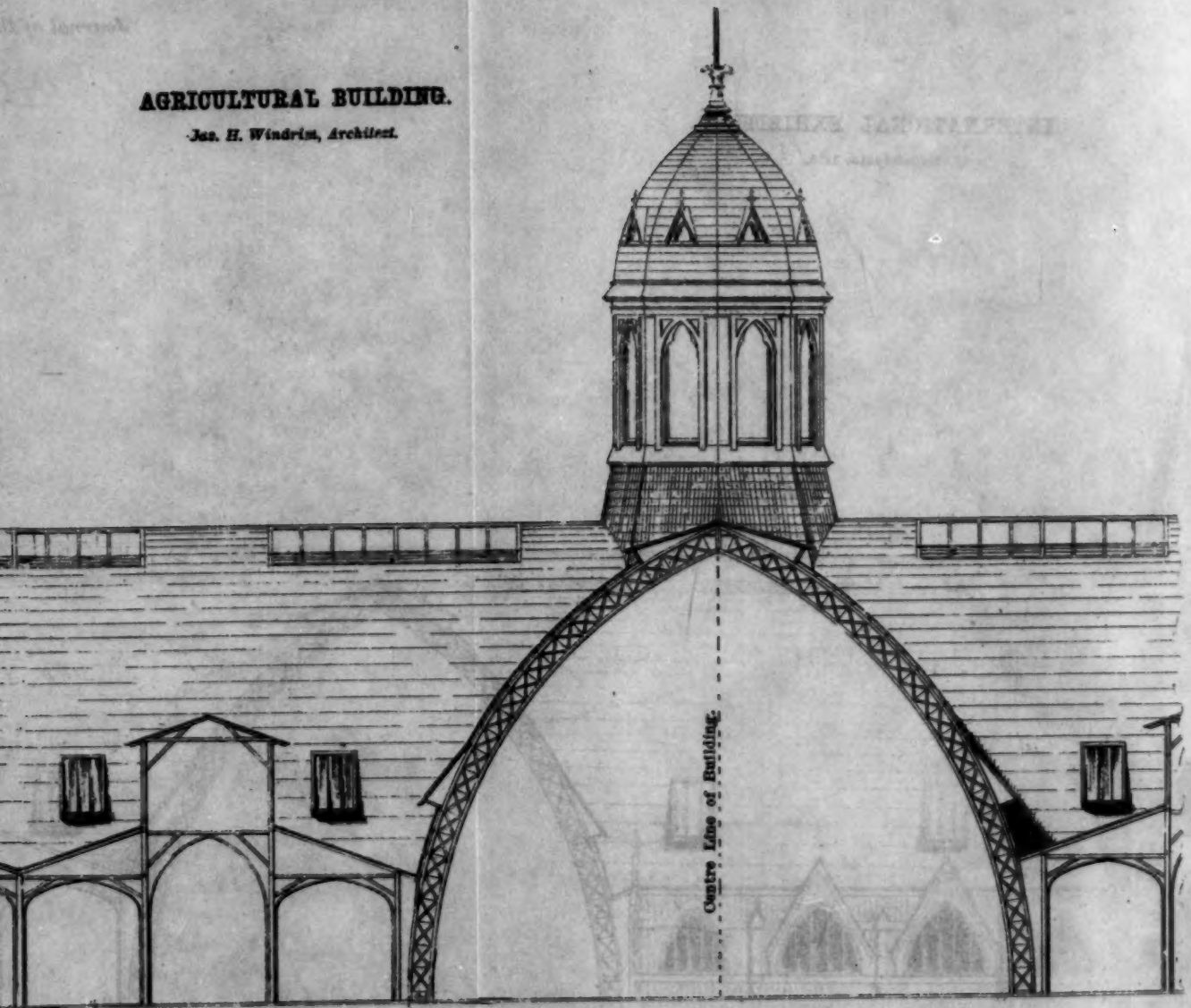
Section a



Section on Line "IK."

AGRICULTURAL BUILDING.

Jas. H. Windrim, Architect.



INTERNATIONAL EXHIBITION
Philadelphia, 1876

very remarkable fact, and reflects very much to the credit and skill of those having her in charge.

The furnace, as stated, was banked or damped down December 4, 1874. The iron, etc., having all been run out she was filled wholly with Connellsville coke. Great care was taken in stopping her up, and every precaution known to furnacemen to have the *fire* remain until advisable to resume operations. We did not expect at the time, however, it would be necessary for her to remain idle more than two or three months at the furthest, but as the market presented no inducements to make iron, she was allowed to stand idle until July 9, 1875. During this *entire* time not a thing was done to her or a *pound of fuel added*. When opened at date given, two-thirds of the amount of coke put in was in good *live* condition, with *plenty of fuel* to commence with. After clearing away the accumulation of ashes from the bottom of the hearth, the tuyere irons were placed in position and blowing commenced, the furnace being ready to resume operations and in as good shape and condition as if only stopped for a few weeks.

The Emma Furnace is 65 feet high, 16 feet bosh, and 8 feet across at tuyeres. When stopped up was making 48 to 50 *gross tons* of iron daily, and is making the same at present, reducing Lake Superior ores with Brier Hill coal and Connellsville coke. Mr. Jas. Paton is General Superintendent, and Mr. Elias Metzler, furnaceman. We ask if this record has ever been equaled or excelled, and should be pleased to hear from you or your correspondents and readers through the columns of your valuable paper in reference to the subject.

Yours truly, S. A. Sague.

The Channel Tunnel.—We learn from the *Times*, (London) that at the recent half-yearly meeting of the Southeastern Railway, held under the presidency of Sir E. W. Watkins, M. P., that the following resolutions were proposed by the chairman and adopted:

"That the directors be authorized, if they should think fit, in accordance with the provisions of the Southeastern Railway Act, 1874, to apply any moneys under their control, not exceeding £20,000, towards the cost of any soundings, and of any borings, shafts, driftways, or other works in connection with the construction of the tunnel under the English Channel."

Pressure Gauge to Register Fifty-four Thousand Pounds.—We have been shown one of Shaw's mercury-column pressure gauges (illustrated and described on page 153, vol. lxvii, of the JOURNAL,) just completed for a company in this city to register fifty-four thousand pounds per square inch. The body of this gauge was forged solid from the best Midvale steel, and bored and turned to the proper shape. The total height is six feet, and the mercury column being four and a half feet. The area of the large plunges is eight and one-half inches and the small one is three-sixteenths, and the movement about one-thousandth of an inch. This is no doubt the highest range of pressures for which a gauge has ever been built.

Bibliographical Notices.

A CENTURY AFTER: PICTURESQUE GLIMPSES OF PHILADELPHIA AND PENNSYLVANIA. Published by Allen, Lane & Scott, and J. W. Lauderbach, Philadelphia, 1875.—This beautiful work is being published in fifteen semi-monthly parts, three of which we have already received, and these well sustain the promise at the commencement that the work would illustrate this city and state with all the resources of art. The subject is well portrayed by pen and pencil; the work is rich in representations of scenery and buildings of historic interest, relieved by occasional figure pictures of life and character. The designs are made by a number of our best artists and are engraved on wood in the most spirited and artistic manner, by Mr. J. W. Lauderbach, who stands at the head of his profession in this city, and is second to none in the country, in the beauty and fine quality of his engravings.

The literary conduct of the work is in the charge of Edward Strahan, and the good taste evinced is in harmony with the general fine character of the work. Much of the progress of the art of engraving on wood is due to the great improvement in typographic printing in late years; there has been little encouragement to the artistic engraver to show the capacity of his art, as without good printing, the best engraving is sacrificed. "A Century After" is most beautifully printed on fine toned paper, and thus the fine qualities of the illustrations are well presented. We hope the work will be well sustained by the public, as no worthier publication of its class has been presented for patronage.

Civil and Mechanical Engineering.

DESCRIPTION OF THE PERNOT FURNACE.

Translated from the French of M. Armengaud.

By William F. Durfee, Engineer.

Description of a Furnace with an inclined rotating bottom for the Puddling of Iron and the manufacture of Puddled Steel; invented by M. Charles Pernot, Engineer and Superintendent of the works of Petin, Gaudet & Co., at St. Chamond.

During a professional journey, we had the good fortune to see an apparatus which at once commanded our particular attention. We speak of the furnace with movable inclined bottom of M. Pernot, which we saw in operation quite recently at the establishment of MM. Petin & Gaudet, at St. Chamond. We were so much impressed with the results of this ingenious apparatus, which are established beyond doubt, that we think this communication to our readers (which is entirely reliable) will be received with great interest.

The first of these furnaces (the one originally erected, and which was for a long time the subject of the most serious study by its inventor) is used for the mechanical puddling of iron, an operation both delicate and difficult, and one which has occupied the attention of many persons in recent years.

The second furnace is intended for the manufacture of puddled steel, and is destined to replace with advantage various inventions more or less complicated and expensive, designed for the same purpose. These, therefore, seem two important inventions which may introduce great changes in the metallurgy of iron and steel, as they have the double merit of simplifying the hand-work and giving many other economical results without necessitating material changes in works already erected.

We have explained in a preceding volume the general character of "The Danks'" system, and also described the modifications it has received in the rotating furnace of Mr. Wm. Sellers; we have also mentioned that M. Siemens has made a valuable contribution to it by his invention of the regenerative gas furnace. It is not necessary to the purpose of this description to note the advantages or disadvantages of the puddling furnace of M. Danks, but we will briefly describe his process, which by its novel character and the boldness of its conception has greatly excited the public curiosity. For this purpose we think we cannot do better than to reproduce the notes of M. Jules Petin, Jr., mining engineer, who also visited England for the purpose of investigating this new invention. "We think," says M. Petin, "that the greatest economy of the process of M. Danks arises from the great quantity of iron which can be treated at a single operation." Not only can 661·42 lbs. (300 kilo's) be treated at one time by this means, but it is possible to operate on 1102·36 lbs. (500 kilo's) and upwards, as was stated by M. Danks, Jr. in the presence of MM. Pernot and J. Petin.

Although it is possible in the course of experimental working to produce a single "ball" of 650 to 1100 lbs., yet practically these masses are divided into several "balls." For working the larger "balls" special tools are necessary; the steam-hammer though of great power, is not convenient for this purpose and the manipulation of the "balls" by men alone is absolutely impossible.

"M. Danks invented and constructed a gigantic camb-squeezer with a hammer at the end, which squeezed and hammered at the same time. Notwithstanding its high cost, the employment of this instrument afforded a partial solution of the difficulty, but did not remove it. The "ball" after squeezing is not in a shape to be practically useful, its dimensions [39·37 in. (1 meter) long, by 11 to 15 in. (3 to 4 decimeters) in diameter] prevent its passing through rolls of ordinary size for conversion into bars unless reduced by the steam-hammer. It will undergo a considerable reduction of temperature by this work, and must then be reheated and divided by a "cutter" under a steam-hammer, otherwise it will be necessary to construct rolls of sufficient size to take the "bloom" directly from the squeezer. We may form from the foregoing some idea of the expense necessary for changing a works from the old method of puddling to the new system of Danks.

"The following is a list of the principal apparatus used in the establishment of Erymus, at Stockton, (England), for twelve Danks' furnaces: 2 cupolas on the Thomas' system; 12 Danks' furnaces; 2 reheating furnaces; 2 12-ton shingling hammers; 2 sets heavy rolls; 1 Danks' squeezer; 4 auxiliary steam boilers, the steam produced by the waste heat not being sufficient to work the rolls.

"For a new works the relative expense will be considerably increased, and in reconstructing works already established, the almost total loss of the old material augments enormously the cost of the introduction of the new system."

It must be remembered that the principle of rotation applied to puddling furnaces has been public property for many years in France as well as in adjoining countries, since the first patents taken out for this object are dated in 1853. Be it as it may, of all the systems that have been proposed up to the present time, we believe that of M. Danks to be best known, particularly in the United States, as having given relatively the best results. However, we do not think it will progress with the same rapidity and ease with ourselves as with others for the reasons already given, especially in the presence of the Pernot furnace whose simplicity and economy are so very remarkable.

Principles of the Pernot Process.—Applied to the Mechanical Puddling of Iron.

The process invented by M. Pernot but distantly resembles the foregoing, as we shall see. He takes an ordinary puddling furnace and makes the bottom independent, it is in fact a kind of great circular basin which is inclined so as to be but partially covered with the bath of molten iron. This basin, which the workmen call the "pot," is mounted on an oblique axle, and receives a rotary movement which constantly displaces the fused metal. At its junction with the fixed part of the furnace there is an allowance for play of from 1 to 1½ inches (3 to 4 centimeters).

The ash-pit is tightly closed and into it the blast is introduced, which when operating causes the flame and the gas which fill the furnace to pass over the movable bottom without escaping at the joint which exists between it and the fixed parts, and without allowing the penetration of the exterior air, for the equilibrium of pressure of the air and the gaseous products of combustion is an essential condition, and

is an advantage which renders the process completely practical by reducing the repairs of the joint which is reasonably durable. A continuous stream of cold water is projected during the operation upon the outside of the "pot," which is thus cooled and maintained in a perfect state of preservation.

We know that in the ordinary furnaces with fixed bottoms, they have the same cast iron bed which is exposed to the action of the cinder and flame, and that the parts forming the inside of the bottom do not suffer from their action, but part with the same degree of heat they receive. It is the same with the inclined movable "pot," all the molecules of the metal are successively exposed in thin layers for a short time and are carried round and elevated by the rotation, into the upper part of the furnace, and yet they are not unduly exposed to oxidation because as they arise they again descend and are plunged in the bath of iron which is in the lower part of the furnace.

"The following conditions," says M. Petin in his paper, read before the French Society of Civil Engineers, and the Iron and Steel Institute at London, "exist in the mass from various causes during the progress of the heat:

"1st. The temperature produced by the heat of the fire urged by the blast is very regular.

"2d. Each part of the bath is heated successively in thin layers as we have before stated, instead of being heated by the surface alone, as in ordinary furnaces.

"3d. The heat arising from the chemical re-actions produces an intermolecular combustion which has been compared by M. Jordan to some of the phenomena of the Bessemer process, and which is manifested in the most energetic manner."

The whole movable apparatus is mounted on a four-wheeled car, which permits its being easily withdrawn from the furnace which it is necessary to do in order to facilitate repairs, and this mechanical combination presents the advantage of not losing the time which in other furnaces attends their complete cooling in order to allow of the repairs which are required after one or more operations. Farther on we will give the results obtained in recent experiments with irons of various kinds in this furnace, which appear to us valuable; of these results we will give an exact account, which will show the progress already made.

DESCRIPTION OF THE PERNOT PUDDLING FURNACE.—REPRESENTED BY THE ACCOMPANYING FIGURES.

Fig. 1 is a longitudinal section taken through the axis of the furnace, along the line 1–2 of the plan, (Fig. 2.) Fig. 2 is a horizontal section, taken at the height of the line 3–4–5, and passing above the movable bottom, as is seen on the plan. Fig. 3 is a transverse section passing through the axis of the movable "pot," along the line 6–7, (Fig. 2.) Fig. 4 represents an exterior elevation of the "pot" and its carriage withdrawn from the fixed part of the furnace. Fig. 5 shows the under side of the "pot." Fig. 6 is a section of the furnace along the line 8–9, and shows from above, the carriage on which the "pot" turns when in use.

All these figures are drawn to a scale and represent an apparatus sufficiently large for the treatment of from 2200 to 2600 lbs. (1000 to 1200 kilogrammes) of metal at a time, and for the making of eight charges in twenty-four hours, which will correspond to a product of from eight to nine tons. As will be seen, the apparatus is composed of two distinct parts, the one fixed and the other movable. The first nearly resembles, in general appearance, an ordinary puddling furnace, with the exception of the lateral sides A and A′, (Fig. 2), which are considerably swollen in the middle instead of being the prolongation of the side wall of the fire-box B.

The roof, C, also presents in the elevations and vertical sections a great similarity to the old form of furnace with a fixed bottom, particularly over the grate and at the flue which conducts the smoke to the chimney. But the central part is circular, as may be seen in the horizontal section Fig. 2, and corresponds in diameter to that of the movable bottom, and is exactly the shape of the edge of the "pot." From 1 to 1½ inches (3 to 4 centimeters) above the circumference of the upper edge of the "pot" is placed a ring of cast iron, *a*, at the same inclination as that of the bottom of which in fact it is an extension, it is supported by massive masonry and serves to receive and sustain the fire-brick portion of the furnace. In front of the furnace are placed the two working doors D, through which are introduced the materials to be treated, and which are entirely closed during the early part of the operation, but are opened when the metal has arrived at a state of fusion and "rabbling" is required, finally the

separation of the metal is effected and the several "balls" are successively taken out, which is rendered very easy by the "pot" being made to change its place.

The fire-box, B, is completely closed during the working, and the fire is urged by a blast supplied by a fan blower, by means of a pipe whose outlet is at *b*. The "stoke-holes," *c*, through which is introduced the fuel, are stopped with fine coal without difficulty. The "sight holes," *d*, are arranged in the end of the furnace in order to allow an examination of the interior when necessary; and are firmly closed by a plate of cast iron, *d'*. The ash-pit is likewise tightly closed by means of two hinged doors of plate iron, E, in order that the blast may be forced through the grate.

As in ordinary furnaces, the whole of the exterior of the body of the furnace is composed of plates of cast iron, F, adjoining one another, these are retained in position by the rails, G, which replace with advantage the square bars and angle-irons commonly used. The second part of the apparatus, that which is a substitute for a fixed "bottom," properly so called, consists principally of a large tub, H, (called by the workmen the "pot") whose interior surface is formed by a lining of ore which is placed on a bottom plate, I, of plate iron, and against a cylindrical envelope composed of numerous plates of cast iron bolted and keyed together, forming a rim, J. These plates, which can be removed and replaced with ease, are pierced with holes so that they can be penetrated by jets of water which are carried around the envelope and serve to keep the lining continually cold, notwithstanding the high temperature of the furnace. Beneath the bottom plate, I, is placed a bevel wheel, K, which gears with the bevel pinion, L, by which the "pot" is given a rotary movement of two or three turns per minute.

The axis of this pinion is prolonged, (as may be seen in Fig. 2) and carries at its other extremity the bevel wheel, M, which by means of the small pinion, N, receives the power of a double cylinder steam engine coupled to the shaft of pinion N by cranks at right angles, thus avoiding dead points and the employment of a fly-wheel. Four conical rollers, P, are placed beneath the bottom of the "pot" and which roll on the circular track, Q, which instead of being horizontal, presents on the contrary an inclined plane, which obliges the whole of the movable bottom to have the same inclination while revolving and thus in proportion as it turns it constantly displaces, as

we have before said, the fused materials which are consequently most rapidly and regularly heated. The axles of the rollers are held in bearings of cast iron, fitted and bolted beneath the bottom plate I. The whole of this machinery is skillfully combined to give the apparatus the firmness and solidity desirable and to insure a rotary movement of perfect regularity, without shock or noise, and which is easily controlled, notwithstanding the weight of materials which it contains, and the high temperature of the furnace.

The circular track, Q, forms a part of a four-wheeled carriage, R, which runs on two parallel rails, S, which serve to introduce the apparatus into the interior of the furnace, as is shown in Figs. 1, 2 and 3, and for withdrawing it as is seen in Fig. 4. This arrangement is most important, as it allows necessary repairs to be immediately made, without loss of time, whereas in the old-fashioned form of furnace it is essential that it should stand without firing fifteen or twenty hours before it is sufficiently cool to allow the workmen to enter it.

The furnace which we have described, and which is in daily use at the works of St. Chamond, has a movable "pot" of a mean diameter of 94½ inches (2·40 m.) which corresponds to a surface of 48·7 square feet (4·522 m.), and it is able to treat one ton of metal per charge although its relative depth is very small.

In the first furnace tried by M. Pernot, and which was erected at the works of Petin & Gaudet, these dimensions were much smaller and only sufficient for the treatment of from 661·2 lbs. to 1000 lbs. (300 to 400 kilo's) per charge.

With the present apparatus from four to five charges per turn of twelve hours can be worked without difficulty, drawing seventeen or eighteen "balls" or "loops" at each, the last being as hot as the first. The continuous rotation of the bottom enables the workmen to divide the "balls" with ease, by bringing all parts of the fused metal successively before the working doors, and this rotation also enables the removal of the balls when formed to be accomplished without difficulty.

Preparation and Management of the Apparatus.—Preparatory Operations.

After drying a new furnace and raising it to a white heat, we oxidize some "scrap" in the same way as in the ordinary system of puddling, for filling all the joints formed by the pieces of iron ore which are

placed around the sides of the furnace, and finally we have a united smooth surface without fissures. As soon as the "scrap" becomes hot, we shut off the blast to oxidize and make it flow, this is quite necessary in furnaces that are worked with a blast, as the flame repels the air and will not permit it to enter the doors.

During all the time required for heating and oxidizing the "scrap," which is about one hour, the bottom remains fixed, or is allowed a movement of but two or three turns per minute, which corresponds to a circumferential speed of from 1 to 1½ inches (25 to 40 centimeters) per second. As a result of the rotation, the liquid oxide of iron covers the entire bottom, and the puddler covers the sides of the "pot" with the aid of a tool called a bottom-paddle.

The movement imparted to the apparatus renders the operation of preparing a lining a very easy one, and the streams of water which are conveyed to the exterior envelope, as we have seen, prevent the sides from getting hot, and at the same time cool the bottom, and these jets produce a real economy in the expense of repairs of the furnace. The bottom being prepared in the manner described, its cooling finished, and its hardening complete, the grate is then cleaned and the furnace is ready to receive its "charge." The bottom is repaired by burning or oxidizing more "scrap" whenever it is thought to be too thin.

Charging and Managing the Furnace.

We will now proceed to follow the treatment of a charge of one ton (1000 kilo's), of for example the white mottled charcoal iron of Toga, which we often saw used at the works of St. Chamond. After having introduced into the apparatus the hammer slag, or scales, from the rolling mill, and spread them properly in the usual manner, we charge the required quantity of pig-iron, which has already been heated in a special furnace of sufficient size to supply all the puddling furnaces in the mill, next we turn the blast under the grate, the "pot" remaining stationary; nevertheless if its exterior envelope begins to get red hot, we throw the jets of water upon it, at the same time giving it a few turns. The charge is soon raised to a bright red heat and then begins to melt and in about thirty-five or forty minutes it is completely fused.

It is at this moment that the operation of "rabbling," properly so called, really commences. We know that in the fixed furnaces this

Fig. 1.

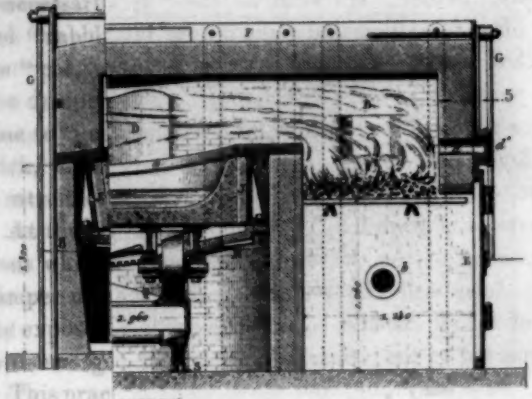
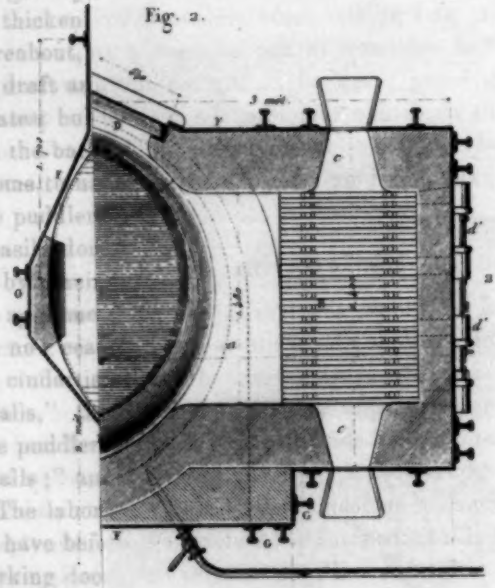


Fig. 2.



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Pernot Furnace for treating 1 to 1½ Tons of Metal per charge, and 8 or 9 charges per 24 hours.

Fig. 3.

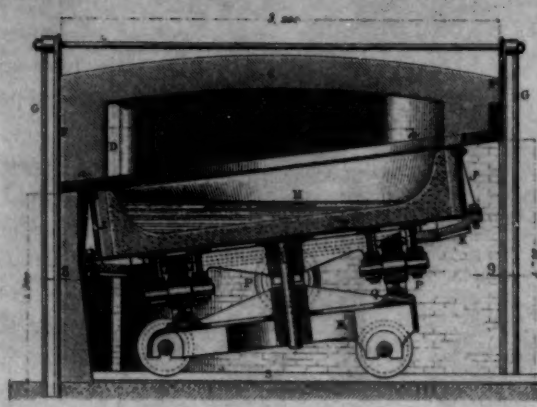
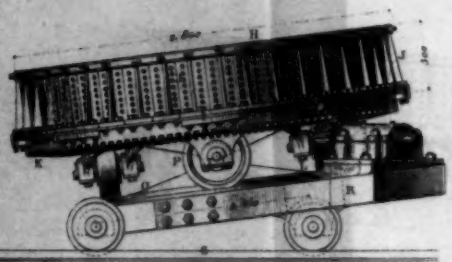


Fig. 4.



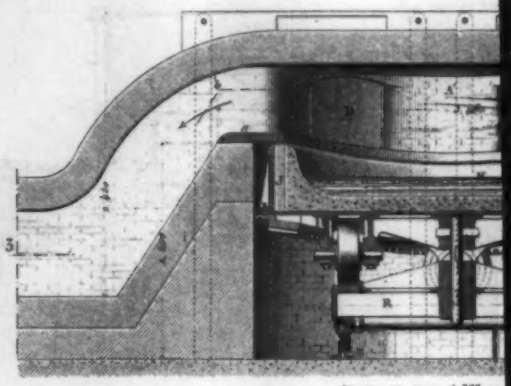


Fig. 6.

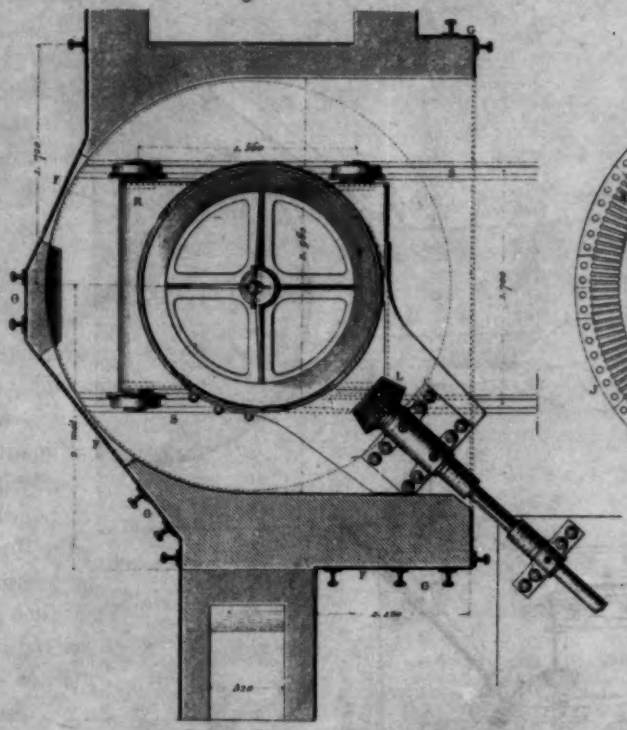
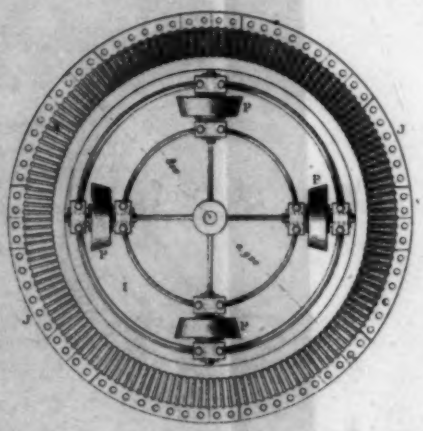
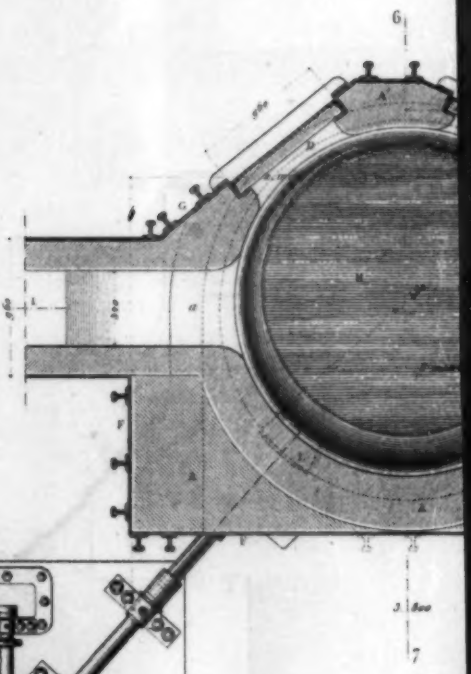
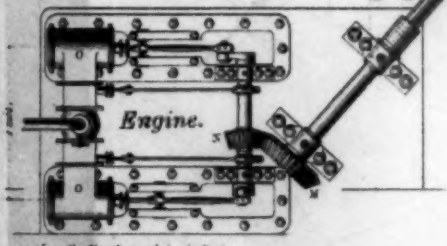


Fig. 5.







ons of Metal per charge,
24 hours.

Fig. 1.

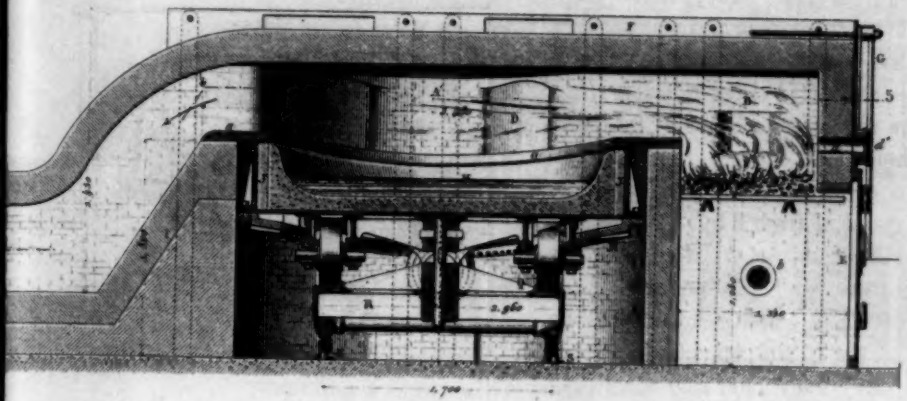
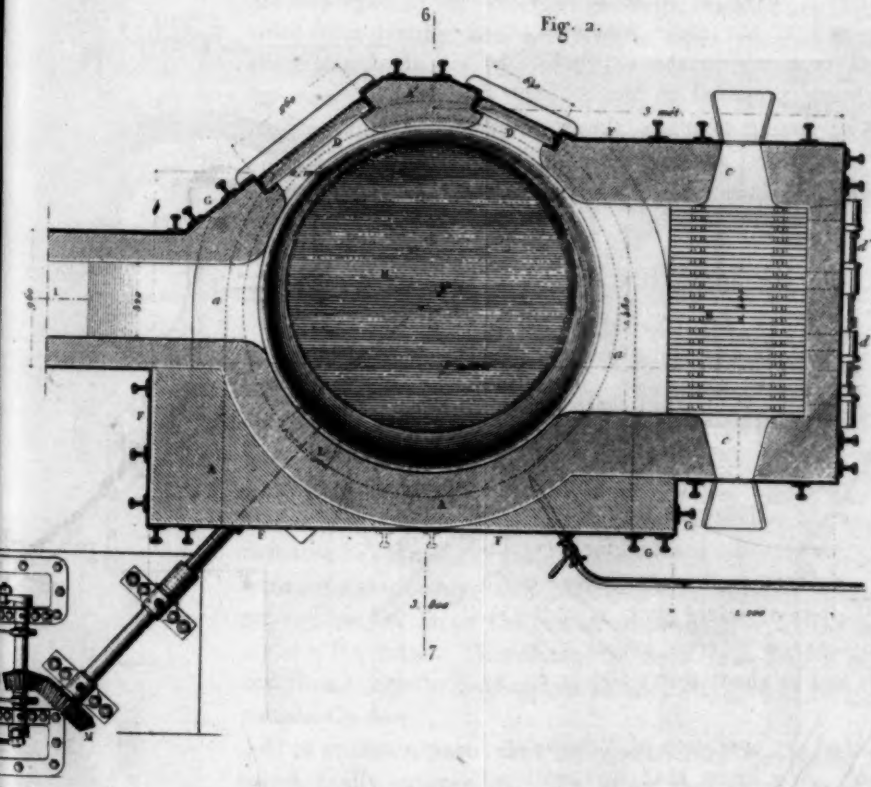


Fig. 2.



operation is performed by hand, and by the skill of the workman, and is necessarily very expensive, but in the Pernot furnace the mixing and "rabbling" are effected without hand labor, by the rotation of the "pot," which is accomplished in the manner previously described. The damper applied to the top of the chimney is manœuvred from time to time by the puddler to suit the different conditions of the work, which are ascertained by testing the bath with a "peel," which is introduced through one of the working doors.

At the commencement of the operation, and principally with grey irons which require considerable time to melt thoroughly, we keep the damper nearly closed. We hasten this first period by throwing on the exposed parts of the bottom jets of water, which harden it as fast as it emerges from the liquid mass.

This practice has the additional advantages of protecting the "pot," and greatly reducing the expense of repairs. For the charge named, the thickening commences by the end of a quarter of an hour, or thereabout, and we gradually raise the damper in order to obtain all the draft and heat possible. At this time the bath has swollen to its greatest bulk. The boiling continues during ten or twelve minutes, and the bath then commences to diminish in volume, and the iron to "come to nature;" the "pot" has been kept turning all this time. The puddler is careful to aid the operation with his "rabble," which is easily done in this furnace, notwithstanding the mass of material; for by placing the rabble firmly in the door and supported against it, the agglomerations of iron become separated as fast as they form. We now cease turning and work the metal until it is so condensed that the cinder is completely separated, and it is ready to be gathered into "balls," this period occupies from twenty to twenty-five minutes. The puddler now proceeds to divide the mass, and to make it into "balls;" and will take out the first in about ten minutes.

The laborious work of "balling" is facilitated to the puddler, as we have before said, by the fact that it is always done in front of the working doors, by allowing the "pot" to make the necessary movement, without his being obliged to collect the iron which he finds on the right and left hand and pull it before him.

The "balls," in order to be handled without difficulty at the steam-hammer and the rolls, are generally of the weight of from 120 to 130 pounds (55 to 60 kilo's), and from the charge of one ton there is in fact produced seventeen or eighteen balls, which are obtained in about an

hour, and the bars rolled from them are remarkably clean and exempt from cracks. Finally the duration of the complete operation is less than three hours, which includes the time lost in charging another heat which allows from eight to ten charges per twenty-four hours. When "refined" iron is treated, a single furnace produces eight or nine tons of iron per day, and two thousand five hundred (2500) to two thousand seven hundred (2700) tons per year.

Results of Experience.

MM. Petin & Gaudet have very properly required us to communicate the results of the various trials which they have made at the furnace of M. Pernot since it commenced working. We think them particularly interesting as they furnish the proof that this system has arrived at a state entirely practical, and that it is called to render great service in metallurgical establishments.

Works at Saint Chamond.

At the outset in the first table (which is taken from the manufacturing books of the forge at St. Chamond) we have an exhibit of the economic results of the puddling of two hundred and ninety tons of refined pig-iron, and fifty tons of common pig-iron.

Materials charged in the furnace.		Weight and Kind of Iron Puddled.	
		Refined pig.	Common pig.
Charged for the production of 2240 lbs. of puddled bar.	Pig Iron, . .	2288 lbs.	2378 lbs.
	Coal, . . .	2863 "	1603 "

Upon examining this table we find the following results:

1st. The loss in puddling refined iron is forty-eight pounds per ton of bars produced, while it is as much as one hundred and thirty-two, and sometimes one hundred and fifty-four pounds in the old form of puddling furnace.

2d. The loss in puddling common pig iron is one hundred and thirty-eight pounds per ton of bars, instead of from 265 lbs. to 352 lbs., as is common in the old system.

We notice also a great difference in the consumption of fuel. Thus for refined iron, 2863 lbs. are burned instead of 3902 lbs., which is commonly used, a saving of 1039 pounds at least, and for "common pig," the consumption is 1603 lbs., when it was 2579 lbs. in the old puddling furnace, which shows an economy of 976 lbs. of coal per ton of iron.

The net cost (also taken from the manufacturing books of these works) compared with that of the old system, shows a difference of about $9.50 per ton of finished iron, an advantage of the new process, of which we will be convinced by the following comparative details.

PUDDLING BY THE PERNOT FURNACE.—MANUFACTURE OF FINISHED IRON, (FEBRUARY, 1874.)

Days' Work of Furnace		CONSUMPTION. Coal.	Pig Iron.	Wrought Scrap.	Roll Scales and Iron Ore.	Production.	Charged to produce 2240 lbs. Coal.	Pig Iron.	Wrought Scrap.	Roll Scale and Iron Ore.
						Lbs.				
27	2½	Lbs.	Lbs.	"	Lbs.	199,900	Lbs.	Lbs.	"	Lbs.
		236,235	207,129		10,154	or	2,650	2,321		105
						89·24				
						Tons.				

Average product of the furnace per day, 7404 lbs.

EXPENSES.			Net cost per ton of finished bar.
178,184 lbs. — 79·54 tons of Toga Iron, E.R.,	@ $36.51 —	$2,904.00	
25,902 lbs. — 11·56 tons of Toga Iron, S.L.R.,	@ 36.52 —	422.17	
1,764 lbs. — 0·787 tons of Toga Iron, E.S.R.L.,	@ 36.52 —	28.74	
1,279 lbs. — 0·57 tons of Toga Iron, B. E.,	@ 38.50 —	21.95	
207,129 — 92·457	Average price, $36.522 —	$3,376.86	$37.842
6,615 — 2·95 tons of Roll Scales,	@ $4.11 —	$12.12	
3,539 — 1·58 tons of Mokta Ore,	@ 6.98 —	11.02	
10,154 — 4·53 tons.		23.14	.25
236,235 — 105·46 tons of Coal,	@ $3.42 —	$360.67	4.04
Labor,		241.46	2.75
Cost of repairs,		181.86	2.03
General costs of manufacture,		52.07	.58
Other items of cost,		56.74	.63
		$892.80	
	Total,	$4,292.80	$48.12

NOTE—The quantities in this and the following tables have been made to conform to the ton of 2240 lbs. (1016 kil's) instead of that of 2204 lbs. (1000 kil's) as is the case in the original. W. F. D.

PUDDLING BY THE OLD SYSTEM.—MANUFACTURE OF FINISHED IRON, (FEBRUARY, 1874.)

Days' Work of Furnace		CONSUMPTION, Coal.	Pig Iron.	Wrought Scrap.	Roll Scales and Iron Ore.	Production.	Charged to produce 2240 lbs. Coal.	Pig Iron.	Wrought Scrap.	Roll Scale and Iron Ore.
259	5	Lbs. 1,098,002	Lbs. 673,451	Lbs. 46,827	Lbs. 22,996	613,213 or 273·8 Tons.	3,798	2,460	171	86

Average product of the furnace per day, 2,368 lbs.

		EXPENSES.			Net cost per ton of finished bar.
204,812 lbs.	— 90·43 tons,	Gray Clavieres pig, @	$37.71 —	$3,410.12	
369,591 lbs.	— 164·99 tons,	Soft Toga pig, E. R., @	36.51 —	6,022.79	
55,301 lbs.	— 24·73 tons,	Toga pig, E.S.L.R., @	36.52 —	903.14	
11,797 lbs.	— 5·26 tons,	Toga pig, B.E., @	38.50 —	202.51	
31,950 lbs.	— 14·24 tons,	Toga pig, M.S.L.R., @	36.51 —	519.90	
673,451 lbs.	— 300.65	Average price —	$36.78 —	$11,058.46	$40.39
46,827 lbs.	— 20·9 tons,	Wrought scrap, @	$21.29 —	$444.96	
22,775 lbs.	— 10·13 tons,	Roll scale, @	4.11 —	41.63	
220 lbs.	— ·093 tons,	St. Leon Mokla ore @	6.98 —	.65	
69,822 lbs.	— 31·123			$487.24	1.77
1,098,002 lbs.	— 490·18 tons	Coal, @	$3.42 —	$1,676.41	6.12
		Labor,		1,544.69	5.64
		Cost of repairs,		460.29	1.68
		General costs of manufacture,		339.45	1.24
		Other items of cost,		363.01	1.33
				4,383.85	
			Total,	$15,929.55	$58.17

HORME FORGES.

The trials which have been made in the Pernot furnace of the irons of the Horme Co., in the presence of M. Roche, engineer, and superintendent of the manufacture, have also all given satisfactory results as is seen from the record of a few of them contained in the following table.

The problem presented, was to produce puddled iron of ordinary quality (similar to that which is habitually made in these works) by the use, as fuel, of small semi-bituminous coal and coal dust mixed, in the proportion of one part small coal to five parts dust, the mixture weighing 54 lbs. per cubic foot. They have worked sometimes with pig iron alone and sometimes have added turnings of wrought iron, or iron ore. The work commenced on the 20th of April in furnace No. 2, and was continued without stopping during six consecutive days, until the 25th.

TRIAL OF IRON IN THE PERNOT FURNACE BY THE HORME CO.

A. D. 1874.	Days' Work of the Furnace.	Number of Charges.	Pig Iron used.	Turnings and Scrap.	Iron Ore added.	Hammer Slag or Roll Scales.	Consumption of Coal.	Product of Iron,	
								Puddle bar.	Scrap.
April.			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
20	1	5	11,025			661	7,087	10,186	
20	1	4	8,820	1,764		661	6,704	8,123	841
21	1	5	11,025			661	6,896	10,412	
21	1	4	8,820	1,764		661	6,704	8,330	778
22	1	4	8,820	1,764		661	6,704	8,364	748
22	1	5	11,025		1,565	1,102	7,087	10,293	
23	1	5	11,025			661	7,279	10,498	
23	1	5	11,025			882	6,896	10,498	
24	1	5	11,025	882	1,587	882	6,704	10,401	267
24	1	5	11,025			772	7,279	10,421	
25	1	5	11,025		1,709	772	6,704	10,455	
Totals	11	52	114,660 or 51·2 tons.	6,174 or 2·75 tons.	4,861 or 2·17 tons.	8,376 or 3·74 tons.	76,044 or 33·94 tons	107,981 or 48·2 tons.	2,634 or 1·17 tons.

On examining the foregoing table, we find 11 days' work of 12 hours each, and 52 charges of pig iron weighing in the aggregate 51·2 tons, which produced (with the addition to a few of these charges of a small quantity of scrap or ore) 48·2 tons of puddled iron, and 1·17 tons of iron from the scrap; and we find a consumption of

33·94 tons of coal. If we add to this amount 1·79 tons, which were used for "lighting up" the furnace, we find that at the expense of 35·73 tons of fuel we have obtained 49·37 tons of iron. The mean production was 8·94 tons in 24 hours. To re-state the result, we have from a mean of 2378 lbs. of pig iron, 128 lbs. of scrap (wrought iron), and 101 lbs. of ore, obtained 2240 lbs. of puddled bar, and 54 lbs. of scrap bar, with a consumption of 1579 lbs. of coal not including that used for lighting up. Now for the net cost per ton, we have:

PUDDLING BY THE PERNOT FURNACE.

Pig iron,	2,378 lbs. — 1·061 tons,	@	$24.21 —	$25.68	
Coal,	1,578 lbs. — 0·703 tons,	@	3.46 —	2.46	
Wrought scrap or turnings,	128 lbs. — 0·057 tons,	@	17.57 —	1.00	$29.77
Hammer-slag or scales,	174 lbs. — 0·078 tons,	@	4.12 —	0.32	
Iron ore,	101 lbs. — 0·045 tons,	@	6.98 —	0.31	
Deducting scrap bar,	54 lbs. — 0·024 tons,	@	$26.95 —		0.65
					$29.12

There remains for cost of materials,		$29.12	
Labor,	$3.35		
Cost of repairs,	1.18	$5.85	
General costs of manufacture,	.60		
Other items of cost,	.72		
Total,		$34.97	

Thus the net cost of puddling by the Pernot process is $34·97 per ton (2240 lbs.) of iron obtained, supposing that the labor and other expenses remain the same as in the old mode of puddling; which they certainly do not, since we have seen above that the work of the puddlers is greatly reduced, and the daily production of the furnace considerably augmented.

In order to show the relative economy realized by the employment of this system, we give the following figures which have been taken from the Horme Works, and cover the time between the 1st of July, 1873, and the 28th of February, 1874.

PUDDLING BY THE OLD PROCESS.

In 2992 days' work was manufactured 5026·66 tons of puddled bar, for which was used 5801·26 tons of pig iron, 95·1 tons of scrap, 129·62 tons of hammer-slag, and 5489·45 tons of coal. The average product per day was 1·67 tons or 3·34 tons in 24 hours, which is but 37 per cent. of the production of the Pernot furnace. To produce one ton (2240 lbs.) of puddled bar, there was used 1·154 tons (2584 lbs.) of pig iron, 1·092 tons (2446 lbs.) of coal, 0·019 ton (43 lbs.)

scrap, and 0·025 ton (56 lbs.) of hammer-slag. For the net cost per ton we have,

Pig iron,	2,584 lbs. — 1·154 tons, @	$24.21 —	$27.93	$32.23
Coal,	2,446 lbs. — 1·092 tons, @	3.46 —	3.78	
Wrought scrap,	43 lbs. — 0·019 tons, @	22.27 —	0.42	
Hammer-slag,	56 lbs. — 0·025 tons, @	4.12 —	0.10	
Labor,			$3.35	$5.85
Cost of repairs,			1.18	
General costs of manufacture,			.60	
Other items of cost,			.72	
		Total,		$38.08

The difference of cost is at least $3.11 per ton in favor of the Pernot system. Now on the supposition that a furnace produces nine tons in 24 hours, and runs 290 days per year, there would result a profit over the use of the ordinary furnace of $8017.10 per annum. In presence of such results as this, the Horme Forge Co. have not hesitated to agree with M. Pernot for the use of his invention in their works.

TRIALS OF THE IRONS OF THE FRANCHE-COMTE FORGE CO., IN THE PERNOT FURNACE.

Date, 1874.	Days' Work of the Furnace.		Number of Charges.	Pig Iron used.	Iron Ore added.	Hammer-Slag or Roll Scales	Consumption of Coal.	Puddle bar obtained.
	Days	Hrs.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
May 30th.	1	0	5	9,922		661	7,087	9,655
June 1st.	0	9	3	5,954	1,543	496	5,746	5,685
June 1st.	0	3	.1	1,984		165	1,916	1,984
June 2d.	1	0	4	7,938		662	7,662	7,713
June 2d.	1	0	5	9,923		441	7,470	9,497
June 3d.	1	0	4	7,938	1,544	661	7,662	7,453
June 3d.	1	0	4	7,938	1,632	882	7,854	7,888
June 4th.	1	0	4	7,938		662	8,237	7,900
June 4th.	0	8	3	5,964		441	4,597	5,890
Totals.	7	8	33	65,499 or 29·24 tons	4,719 or 2·1 tons.	5,111 or 2·27 tons	58,231 or 26 tons.	63,666 or 28·41 tons

(To be continued.)

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxx, page 40.]

Of the relative economic propelling efficiency of the screws.—The function of a screw being to apply to the propulsion of a vessel the power received by its shaft from the engine, and the power thus received being the net power developed by the engine, that is, the power which remains after deducting what is neccessary to work the engine *per se*, it is evident that the economic propelling efficiency of a screw will be represented by the per centum of the net power developed by the engine, which is expended in the propulsion of the vessel. This per centum will be found on the last line (23) of the preceding tables, numbered from 1 to 6, both inclusive, containing the data and results of the experiments.

In the following table, No. 7, this per centum will be found expressed, relatively for the different screws at the different speeds of vessel from 5·0 to 8·5 geographical miles per hour.

Table No. 7, containing the relative economic propelling efficiency of screws, A, B, C, D, E, F, G, and H.

Relative economic propelling efficiency of screws,	Speed of the vessel per hour in geographical miles of 6,086 feet.							
	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
In per centum of the net power applied to the screw-shaft.								
A, E, and F	79·81	79·09	78·73	78·47	78·23	77·12	75·41	74·05
B	80·71	79·99	79·55	79·20	78·74	77·43	75·55	74·05
C	79·96	79·14	78·59	78·08	77·41	75·72	73·52	71·82
D	78·74	77·82	77·07	76·36	75·39	73·19	70 42	68·43
G	76·78	75 89	75 67	75·36	74·95	73·47	71·27	69·53
H	77·24	76·28	75·65	75·11	74·42	72·51	69·87	68·00
Relatively.								
A, E, and F	0·9888	0·9887	0·9897	0·9908	0·9935	0·9960	0·9981	1·0000
B	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
C	0·9907	0·9894	0·9879	0·9859	0·9831	0·9779	0·9731	0·9699
D	0·9756	0·9729	0·9688	0·9651	0·9574	0·9452	0·9321	0·9241
G	0·9513	0·9487	0·9512	0·9515	0·9519	0.9489	0·9433	0·9390
H	0·9570	0·9536	0·9510	0·9484	0·9451	0·9365	0·9248	0·9183

An examination of the immediately preceding table shows that, at all the experimental speeds, the propelling efficiency of screw B was the most economical, except in the single instance of screws A, E, and F, at the vessel's maximum speed of 8·5 geographical miles per hour, which gave an equal result.

The propelling efficiency of screws A, E, and F ranged from equality with that of screw B at the maximum speed of vessel to 1 per centum less economical at the minimum speed.

The screw C was less economically efficient than screw B by quantities ranging from 1 per centum at the minimum speed of vessel to 3 per centum at the maximum speed.

The screw D was less economically efficient than screw B by quantities ranging from 2½ per centum at the minimum speed of vessel to 7½ per centum at the maximum speed.

These results from screws A, E, and F, and screws B, C, and D, which only differed in that the three latter were composed of less fractions of the pitch than the three former, show that each diminution of this fraction below that of the screws A, E, and F, namely, 0·3570, was economically injurious, the loss of useful effect by the increase of slip consequent on this diminution being greater than the gain of useful effect by the friction of the screw's surface on the water, due to the same cause.

Screw G, composed of nearly the same fraction of pitch as screw B namely, 0·3446, and having the same diameter, had a pitch which differed in kind from that of screw B, and in quantity. It was both greater and, instead of being uniform, expanded continuously from the forward to the after edge of the blades. Screw G was less economically efficient than screw B by quantities ranging from 5 per centum at the minimum speed of vessel to 6 per centum at the maximum speed.

Screw H was the Griffith screw, formed from screw G by decreasing its surface at the centre and at the perjphery. It was less economically efficient than screw B by quantities ranging from 4½ per centum at the minimum speed of vessel to 8 per centum at the maximum speed.

The foregoing relative economic propelling efficiencies of the different screws are for *smooth water with the vessel unaffected by wind.* The effect of a head wind being to increase the resistance of a vessel,

increases correspondingly the slips of the screws, and consequently changes their relative propelling efficiencies, thereby making those which gave the less propelling efficiency when unaffected by a head wind give a still less propelling efficiency when effected by it. In the case of an aft wind this result would be reversed. The trials of different screws in smooth water, with the vessel unaffected by wind, give their relative propelling efficiencies for those conditions only; but if those conditions be changed, these relative propelling efficiencies will change also. A really exhaustive series of experiments on screws would embrace the determination of their relative economic propelling efficiencies in smooth water with the vessel unaffected by wind, in smooth water with head wind and also with aft wind, in rough water with the vessel unaffected by wind, and in rough water with head wind and also with aft wind. Such a trial would show that the relative economic propelling efficiencies of screws of different types, dimensions, and proportions, applied to the same vessel, varied greatly with the varying conditions of wind and water, even to reversal in many cases, so that the screw which gave the highest result under one set of conditions might give the lowest under another.

Of the influence of different surfaces of screws otherwise the same, on the piston-pressure.—It is evident that, with the same engine and the same pitch of screw, abstraction being made of the friction of the screw-surface on the water, the net pressure on the piston of the engine must be the same at the same speed of vessel, let the surface of the screw and its slip be what it may. Accordingly, if we examine the remainder of the quantities on line 8, after deducting those on line 10, and for corresponding columns, in tables No. 1 to No. 4, both inclusive, containing the data and results of the experiments with screws A, E, and F, and B, C, and D, we shall find such to be the fact. The quantities on line 8 are the net pressures on the piston; that is to say, they are the pressures which remain after deducting from the mean gross-effective indicated pressure, (line 6,) the pressure (line 7) required to work the engine *per se*. The quantities on line 10 are the piston-pressures required for overcoming the cohesive resistance of the water by the screw-blades; or, as it is often termed for brevity, though incorrectly, for overcoming the friction of the screw-surface on the water. Making the comparison for the speed of vessel 8·5 geograph-

ical miles per hour, column h of the tables, we have the following results:

Screw.	Net pressure on the piston, (line 8,) in pounds per sq. inch.	Piston-pressure to overcome the friction of the screw surface on the water, (line 10,) in pounds per sq. inch.	Difference of the two preceding columns.	Slip of the screw in per centum of its speed.	Fraction used of the pitch of the screw.
A, E, and F.....	68·1537	3·9665	64·1872	14·57	0·3570
B.....	66·8945	2·8029	64·0916	16·15	0·2799
C.....	66·2274	2·2252	64·0022	19·43	0·1885
D.....	65·5689	1·3901	64·1788	24·24	0·1014

Of the influence of different pitches of screws, be their other dimensions what they may, on the piston-pressure.—With the same engine, it is also evident that, in the case of screws of different pitches, abstraction being made of the friction of the screw-surface on the water, the net pressure on the piston of the engine must, at the same speed of vessel, be in the direct ratio of the pitches, let the other dimensions of the screws, and their slips, be what they may; for the pitch measures the leverage at which the piston-pressure acts, and, when the speed of the vessel is the same, the slip cannot affect the problem, nor, consequently, can the dimensions of the screw other than the pitch, because their only function is to obtain a fulcrum from the water by embracing a sufficient quantity of that mobile substance.

This assumption can be tested by comparing the results from screws A to D, both inclusive, whose pitch is 5·136 feet, with those from screws G and H, whose pitches are 7 feet.

The net piston-pressure, less the pressure required to overcome the friction or the screw-surface on the water, is, for screws A to D, as above determined, 64·11495 pounds per square inch, which, increased in the ratio of 5·136 to 7·000, gives 87·3842 pounds per square inch of piston for the pressure with screw G. On referring to Table No. 5, line 8, column h, we find the quantity 94·4132; and, on line 10, same table and column, the quantity 6·8088; deducting the latter from the

former, we have 87·6044 pounds per square inch of piston, or almost exactly the same as obtained by the calculation from screws A to D, both inclusive.

Making the comparison for screw H in the same manner, we have 64·11495 pounds per square inch of piston with screws A to D, increased to (5·136 : 7 :: 64·1145 :) 87·3842 pounds with screw H. On referring to Table No. 6, line 8, column h, we find the quantity 92·5013; and, on line 10, same table and column, the quantity 5·0530; deducting the latter from the former, we have 87·4483 pounds, which is almost exactly the same as the 87·3842 pounds.

Trials of the machinery of the United States steam-launch No. 4, with screw G, made on the 17th of February, 1870, with the vessel secured to the wharf at the Mare Island navy-yard, Cal.

During the experiments with screws A to H, made with the steam-launch No. 4, in the bay in front of Mare Island, two trials of screw G were made with the vessel secured to the wharf of the navy-yard, at right angles to the current, from the effect of which it was also shielded by the projecting wharf, so that the resistance of the screw was no more affected by the current than if the trial had been in still water. The vessel's draught of water was the same as during the experiments in the bay, and the same indicators and dynamometer were employed.

The trials were made on the 17th of February, 1870, and each lasted thirty minutes, during which a continuous dynamometer-diagram and indicator-diagrams were taken from each end of each cylinder as rapidly as possible; all preparations facilitating dispatch having previously been made.

The machinery was operated for an hour before commencing the trials, to bring it into normal working condition; and during the trials, the steam-pressure in the boiler, the height of the barometer, and the temperatures of the external atmosphere in the shade, of the engine-room, and of the water in the bay, were taken at the end of every three minutes. The number of double-strokes made by the engines' pistons was shown by the register.

The objects of the experiments were to ascertain: 1st. How nearly the thrust of the screw followed the proportion of the square of the number of revolutions made by it in equal time, under the extreme conditions of widely varying power and with the screw acting always at the same place, the water flowing to the screw without the screw

advancing through the water. 2d. To what extent the proportion of dynamometer-power varied from the indicated power under these extreme conditions, and with the greatly varying speeds of pistons and pressures upon them. 3d. The pressure upon the pistons required to work the engines, *per se*. To determine the 3d, the engines, after the completion of the trials, were uncoupled from the line-shafting, and worked at various speeds of piston with the feed-pump pumping at its proper rate to supply the boiler, a considerable number of indicator-diagrams being taken at each speed from each end of each cylinder. The results varied but very slightly, and with the addition of a trifle for the friction of the line-shafting, gave two pounds per square inch of pistons for the pressure required at all speeds of piston to work the unloaded engines.

The data and results of these wharf-trials will be found in the following table, No. 8, arranged in two columns, headed respectively "1st trial", and "2d trial." In the "1st, trial" the number of revolutions made by the screw in equal times was $(\frac{90}{35}:\frac{900}{733}=)2{\cdot}796$ times more than in the "2d trial" a sufficiently great difference to strongly mark the consequences. The squares of the number of revolutions made by the screw in equal time during each trial, compare as 7·8176 and 1·0000 respectively.

The pressure (2 pounds per square inch of pistons) required to work the engines, *per se*, being deducted from the gross effective indicated pressure per square inch of pistons, leaves a quantity called the "net pressure," which, in the two trials, should have the same ratio as the squares of the number of revolutions made by the screw in equal time. The net pressures compare as $(\frac{98.0}{31\cdot7}=)$ 7·1533 to 1·0000. We have seen that the squares of the number of revolutions made by the screw in equal time compared as 7·8176 to 1·0000, which was doubtless caused by the water not flowing in with sufficient rapidity to solidly fill the displacement by the screw as fast as formed. The discrepancy is considerable; the pressure at the high speed of screw being 8½ per centum less than it should have been, had the water on which it acted been as solid as at the low speed. It was observed constantly, during the trials, that there was no surface-current of water flowing from the bow towards the stern to replace the water displaced by the screw. On the contrary, the surface-water was absolutely quiescent; it had no movement in any direction. The water supplying the screw came up from beneath in nearly a vertical column.

The depth of the water at the wharf was very considerable, and it had a free movement between the bottom and the vessel's keel. An unbroken wave or elevation of water covered the screw during its action; the height of this wave varying, of course, with the rapidity of the rotation of the screw.

In the "1st trial," the dynamometrical horse-powers is $\left(\frac{24{\cdot}827}{27{\cdot}916} =\right)$ 0·8894 of the net indicated horse-powers developed by the engines.

In the "2d trial" the dynamometrical horse-powers is $\left(\frac{1{\cdot}255}{1{\cdot}396} =\right)$ 0.8990.

The thrusts of the screw, per dynamometer, in the two trials, compare respectively as $\left(\frac{1093{\cdot}5}{154{\cdot}5} =\right)$ 7·0777 and 1·0000; while the corresponding net pressures on the pistons compare as 7·1533 and 1·0000.

The distribution of the power, calculated as hereinbefore described, will be as follows for the two wharf trials, namely:

Distribution of the power during the 1st trial at the wharf.

	Horse-powers.	Per centum.
Gross effective indicated horse-powers developed by the engines,	28·486	
Power required to work the engines and shafting, *per se*,	0·570	
Net power applied to the shaft,	27·916 or	100·00
Power absorbed by the friction of the load,	2·094 or	7·50
Power expended in overcoming the cohesive resistance of the water by the screw-blades,	0·878 or	3·14
Power expended in the displacement of the water by the screw,	24·944 or	89·36
Totals,	27·916 or	100·00

The power expended in the displacement of the water by the screw as directly measured by the dynamometer, was 24·827 horses.

Distribution of power during the 2d trial at the wharf.

	Horse-powers.	Per centum
Gross effective indicated horse-powers developed by the engines,	1·600	
Power required to work the engines and shafting *per se*,	0·204	
Net power applied to the shaft,	1·396 or	100·00
Power absorbed by the friction of the load,	0·105 or	7·50
Power expended in overcoming the cohesive resistance of the water by the screw-blades,	0·040 or	2·88
Power expended in the displacement of the water by the screw,	1·251 or	89·62
Totals,	1·396 or	100·00

The power expended in the displacement of the water by the screw as directly measured by the dynamometer, was 1·255 horses.

During the "1st trial" with the vessel stationary at the wharf, the screw made 99·9 revolutions per minute, with a net pressure of 98 pounds per square inch of pistons; and when steaming freely at full power, with the same immersion of the screw, and a net pressure of 94·4132 pounds per square inch of pistons, (Table No. 5, line 8, column h,) the screw made 151·0832 revolutions per minute. Increasing the latter number in the ratio of the square roots of the net pressures, we have ($\sqrt{94·4132} : \sqrt{98·} :: 151·0832 :$) 153·9236, the number of revolutions that would have been made with the vessel steaming freely, had the net pressure on the piston been 98 pounds per square inch. Hence it follows that, *with equal net pressure upon the pistons the screw will make* $\left(\frac{153·9236}{99·9} =\right)$ 54·08 *per centum more revolutions in equal time when the vessel is steaming freely than when it is held stationary at the wharf.*

Again, it will be seen by examining lines 5 and 8, column c, Table No. 5, that when the vessel is steaming freely with a net pressure upon the pistons of 39·2660 pounds per square inch, the screw makes 97·9321 revolutions per minute. Increasing this net pressure in the ratio of $97·9321^2$ to $99·9^2$, we have, for 99·9 revolutions of the screw per minute when the vessel is steaming freely, the net pressure of 40·8602 pounds per square inch. Hence it appears that, revolution for revolution, there was required when the vessel was stationary at

the wharf $\left(\frac{98{\cdot}0000 - 40{\cdot}8602 \times 100}{40{\cdot}8602} =\right)$ 139·84 per centum more pressure to turn the screw then when the vessel was freely under way.

Of course the above two determinations only apply rigorously for the speeds of vessel at which they are made. The results show an enormously greater proportional resistance of the screw when the vessel is stationary at the wharf than when steaming freely under way than is found in the case of large screw-steamers having considerable *length*, and doubtless arises from the fact that when the launch—a small and very *short* vessel—was steaming freely under way, the water did not reach the screw as solidly as it does in the case of long screw-steamers, while, when steaming at the wharf, the difference in this particular was very greatly less.

Table No. 8, *containing the data and results of the trials on the* 17*th of February,* 1870, *of the machinery of steam-launch No.* 4, *with screw G, the vessel being secured to the wharf of the Mare Island navy-yard, California.*

	1st. trial.	2d. trial.
TOTALS.		
Duration of the trial in minutes	30·	30·
Number of double strokes of engines' pistons and of revolutions of the screw	2,997·	1,072·
TEMPERATURES.		
Temperature, in degrees Fahrenheit, of the external atmosphere	54·	59·
Temperature, in degrees Fahrenheit, of the water in the bay	52·	53·
Temperature, in degrees Fahrenheit, of the engine room	80·	83·
ENGINES.		
Number of double strokes made per minute by the engines' pistons.	99·900	35·733
Steam pressure in the boiler, in pounds per square inch above the atmosphere	107·	19·
Position of the throttle-valve	Wide open.	Wide open.
Fraction of the stroke of the pistons completed when the steam was cut off	0·858	0·858
Thrust of the screw, in pounds, per dynamometer	1,093·5	154·5
Height of the barometer, in inches of mercury	29·85	29·84
STEAM-PRESSURES IN CYLINDERS PER INDICATOR.		
In pounds per square inch above zero at commencement of stroke of pistons	119·0	32·1
In pounds per square inch above zero at point of cutting off the steam	112·3	30·1
In pounds per square inch above zero at end of stroke of pistons	93·7	26·5
In pounds per square inch above zero against the pistons during their stroke	18·4	16·1
Mean gross effective pressure on pistons, in pounds per square inch.	100·0	15·7
Mean total pressure on pistons, in pounds per square inch	118·4	31·8
Mean net pressure on pistons, in pounds per square inch	98·0	13·7
POWER.		
Gross effective indicated horse-powers developed by the engines	28·486	1·200
Total horse-powers developed by the engines	33·728	3·240
Net horse-powers developed by the engines	27·916	1·206
Dynamometrical horse-powers developed by the engines	24·527	1·255

Trial of the machinery of the United States steam-launch No. 4, made on the 30th of March, 1870, with screw G, the vessel being secured to the wharf of the Mare Island navy-yard, California, and having its steam raised six inches and held suspended by a floating crane.

This experiment, the data and results of which will be found in the following table, No. 9, was made with the vessel secured to the wharf of the Mare Island navy-yard in such a way that the keel was at right angles to the current. The stern of the vessel was raised six inches and held suspended by a floating crane, which, in common with the vessel, rose and fell with the tide. The object of thus suspending the stern of the vessel above the level at which it floated when resting in the water with its screw not in action, was to enable the engines to make a greater number of double strokes of pistons with the same piston-pressure, in a given time, than they would have done without such suspension; in fact, to make nearly the same number per minute they would have done with the vessel in free motion and the same piston-pressure.

The principal objects of the experiments were:

1. To ascertain the rate of combustion of anthracite in the furnace under the experimental conditions.
2. To ascertain the economic vaporization by the boiler with anthracite at this rate of combustion.
3. To ascertain the indicated and dynamometrical horse-powers developed by the engines.
4. To ascertain the cost of the indicated and of the dynamometrical horse-powers, in pounds of anthracite, in pounds of the combustible portion of the anthracite—that is, of the portion which remains after deducting the refuse in ash, clinker, etc.—and in pounds of feed-water consumed per hour.
5. To ascertain the condensation of steam in the cylinders.

In making the experiment, the same indicators and dynamometer were used as were employed throughout all these experiments. The anthracite was carefully weighed on the wharf and delivered into the fire-room as fast as consumed. The refuse from it in ash, clinker, etc., was collected and weighed in the dry state at the end of the trial, and on the same scales as the anthracite. The feed-water was accurately measured in an iron tank placed on the wharf. From this tank the water was delivered through a hose into a smaller tank on

board the vessel, from which it was pumped in to the boiler by the feed-pump of the engines. In passing from the last tank to the boiler the feed-water traversed the "heater" and had its temperature raised by the exhaust steam of the engines. The feed-water was rain-water.

The temperatures of the external atmosphere, of the engine and boiler room, of the water in the bay, of the feed-water in the tank and when it entered the boiler, were taken every fifteen minutes, by the usual mercurial thermometers. At the same intervals there were noted the steam-pressure in the boiler and the height of the barometer. The throttle-valve was kept wide open, and the point of cutting off the steam remained constant during the trial. The number of double strokes made by the engines' pistons was taken by a counter.

An indicator-diagram was taken every fifteen minutes from each end of each cylinder. The diagrams from the dynamometer were practically continuous.

All the observations were recorded, at fifteen minutes' intervals, in a tabular record.

In commencing the experiment, the engines were operated several hours to bring them into proper adjustment, and the fires to steady action. The latter were then thoroughly cleaned and made about six inches thick, the height of the water in the boiler glass guage marked, the steam pressure in the boiler, and the time noted, and the experiment held to commence. At its end, the fires were again thoroughly cleaned, and left of the same thickness as at the commencement, with the water at the same level in the boiler, and having the same steam-pressure upon it.

RESULTS.

The maximum rate of combustion that could be sustained was 24·655 pounds of anthracite per hour per square foot of grate-surface with a blast up the chimney given up the exhaust of the two cylinders working at right angles to each other, and having a steam-pressure at the end of the stroke of the pistons of 66·8 pounds per square inch above the atmosphere. The number of exhaustions made per minute was 472. The per centum of this anthracite in refuse being 16·23, there were consumed of its remaining or combustible portion, 20·653 pounds per hour per square foot of grate-surface. To have sustained this rate of combustion with natural draught would have required a chimney 60 feet high above the level of the grate.

The economic vaporization for this fuel and rate of combustion, and for the type and proportion of boiler, was very high, being 9·687 pounds of water vaporized by one pound of the combustible portion of the anthracite from the temperature of 212 degrees Fahrenheit, and under the standard atmospheric pressure of 29·92 inches of mercury.

The condensation of steam in the cylinders, other than that due to the development of the power, was 31·76 per centum of the weight of steam generated in the boiler. This large per centum is due to the small size of the cylinders. With large cylinders, working without a condenser, and with the same low measure of expansion—the steam not being cut off until 0·858 of the stroke of the pistons was completed—the condensation, other than that due to the development of the power, would not have exceeded one-tenth what it proved to be with these small cylinders. Nothing could more strikingly show the necessity for using highly superheated steam with small cylinders. The pistons and valves of these were perfectly tight, and the cylinders and steam-pipes were well protected from radiation.

The distribution of the gross effective indicated power developed by the engines, calculated in the manner hereinbefore explained, is as follows, namely:

	Horse-powers.	Horse-powers.
Gross effective indicated horse-powers developed by the engine, ...	27·221	
Power required to work the engines and shafting, *per se*, ...	0·673	
Net power applied to the shaft, . .	26·548 or	100·00
Power absorbed by the friction of the load, .	1·991 or	7·50
Power expended in overcoming the cohesive resistance of the water by the screw-blades, · ·	1·455 or	5·48
Power expended in the displacement of the water by the screw, ...	23·102 or	87·02
Totals, ...	26·548 or	100·00

From the above calculation, it appears that the power expended in the displacement of the water by the screw working with the vessel secured to the wharf, or, what is the same thing, the dynamometrical power by calculation, was 23·102 horses. This power, as directly measured by the dynamometer, was 23·025 horses, or sensibly the same.

During the trial, the force of the blast in the chimney was ascertained by direct measurement. An iron pipe of small diameter was placed immediately over the blast-nozzle, and half an inch above it. This pipe extended vertically to the top of the chimney, over the edge of which it was bent and brought down to a convenient distance, where it was joined to an inverted glass siphon containing mercury. The pressure of the blast in one leg of the siphon forced the mercury up the other leg, and the height of the mercurial column from the mercury-level in one leg to that in the other leg measured it. The mean of a great many observations showed that when the steam pressure in the boiler was 102 pounds per square inch above the atmosphere, the height of the column was 6·6 inches, equivalent to a pressure of 3·24 pounds per square inch.

(To be continued.)

BRIDGE SPECIFICATIONS.

By Joseph M. Wilson, C.E.

Engineer of Bridges and Buildings, Pennsylvania Railroad.

The following specifications of bridges now actually under erection may be of interest to those who have charge of such work, and are here offered with that intention.

SPECIFICATIONS

For masonry of street bridge to be erected over the Pennsylvania Railroad, at Penn avenue, in the City of Pittsburgh, Pennsylvania.

The foundations to be dug out to a depth of six (6) feet below the natural surface of the ground, or to such greater depth, if found necessary, as the Engineer may decide, and to be filled in for the depth of three (3) feet with concrete.

The concrete is to be formed of a hard durable stone, to be approved of by the Engineer, broken into angular fragments of a size to pass through a two-and-a-half ($2\frac{1}{2}$) inch ring, and to be screened.

This stone to be mixed with clear, sharp, river sand, and hydraulic cement, in the proportion of one (1) part cement, one (1) part sand, and four (4) parts broken stone. This must not be mixed in a larger amount than requires one (1) barrel of cement at a time, and must be used as mixed, not being allowed to lay, and then remixed with water and used.

The concrete must be prepared by first spreading out the cement and sand in the proper proportions on a platform of rough boards, and thoroughly mixing then in a dry state. The proper quantity of stone is then to be added, and after again thoroughly mixing the whole, water is to be added as much as necessary to bring the mass to the proper consistency; the materials being mixed as the water is added, until all the materials are thoroughly incorporated, and the surface of each stone is well coated with mortar. This concrete must be placed in the foundations in layers not over a foot thick, and must be either thrown from a height of not less than ten (10) feet, or else each layer must be well rammed until a film of water appears upon the surface, but not enough to make it quake.

Time must be given for the concrete to become firm before masonry foundation is commenced upon it, as heavy pressure tends to retard the setting.

The masonry will be rock range pitch face; the stone to be accurately squared, jointed and bedded, and laid in courses not less than twelve (12) inches thick, nor exceeding twenty-four (24) inches in thickness: decreasing from bottom to top of pier or abutment. The stretchers shall in no case have less than sixteen (16) inches bed; and for all courses above sixteen (16) inches, at least as much bed as face. They generally shall be at least four (4) feet in length. The headers shall be of similar size with the stretchers, and shall hold the size in the heart of the wall that they show on the face, and be so arranged as to occupy one-fifth ($\frac{1}{5}$) of the face of the wall, and when the thickness of the wall will admit of their interlocking, they will be disposed in that manner. When the wall is too thick to admit of that arrangement, stones not less than four (4) feet in length will be placed transversely in the heart of the wall to connect the two opposite sides of it. The stones for the heart of the wall will be of the same thickness as those in the face and back; bedded the same as the face stone but not jointed, and must be well fitted to their places, any remaining interstices to be filled with small sound stones or chips. The face stones

to be set in cement mortar; the interior stones to be laid dry, and every course to be thoroughly grouted. The proportion of sand, cement, and lime in the mortar and grout, to be as directed by the Engineer.

The stones forming the masonry will be generally left with their faces as they come frome the quarry, unless the projection above the neat line should exceed two (2) inches, in which case they shall be roughly scabbled down to that point.

Such coping and such posts for railing as shall be indicated on the drawings, or shall be directed by the Engineer, shall be hammer dressed to the required sizes, and placed as shown.

In all masonry the stone must be of a hard and durable quality, either Derry, Massillon, or Freeport, of good size and shape, to be approved of by the Engineer.

The coping, bridge seats, and posts being the hammer dressed work, are to be of Massillon stone.

Such portions of the masonry as the Engineer may require to be laid in lime or hydraulic cement, to be so laid; the Pennsylvania Railroad Company furnishing, or paying for the lime or cement used, and the contractor furnishing a suitable protection for the cement from the weather.

If, in the progress of the masonry, an increase in the number of headers specified should be required by the Engineer, such additional number shall be laid in the work as he shall designate.

The whole of the construction to be in strict accordance with the drawings furnished by the Engineer of Bridges and Buildings of the Pennsylvania Railroad Company, and under the direction of the Engineer in charge of the work.

SPECIFICATIONS

For superstructure of railroad bridge to be erected near Morrisville Station, on the New York Division of the Pennsylvania Railroad.

General Description.—The superstructure is to be constructed on the triangular girder system, and to consist of four spans, square to the line of the railroad, three of them deck bridges of three trusses, and one a half-through bridge of two trusses, numbering from the west end, the railroad tract having a curvature of five and a half degrees.

The trusses throughout are to be composed entirely of wrought iron, except rollers and bolster blocks on the piers and abutments, having

wrought upper chords of channels and plates, wrought iron upset weldless link lower chord, and wrought iron braces, all with link ends, to be upset without weld. All joints are to be made with pin connections, and sleeve nuts are to be introduced in the laterals and diagonals for adjustment.

The deck spans are to have timber floorbeams, and the half-through span wrought iron built cross girders; white oak track stringers are to be used throughout. The bolsters and abutment plates are to be of wrought iron.

The general dimensions are as follows:

Span No. 1.

Distance, centre to centre of end pins,	73 ft. 6 in.
Number of panels,	4
Number of sub-panels,	8
Length of each panel,	18 ft. 4½ in.
Length of each sub-panel,	9 ft. 2¼ in.
Height of truss, centre to centre of chords,	7 ft. 3 in.
Distance, centre to centre of trusses,	9 ft. 9 in.

Spans Nos. 2 *and* 3.

Distance, centre to centre of end pins,	53 ft. 6 in.
Number of panels,	4
Number of sub-panels,	8
Length of each panel,	13 ft. 4½ in.
Length of each sub-panel,	6 ft. 8¼ in.
Height of truss, centre to centre of chords,	5 ft. 6 in.
Distance, centre to centre of trusses,	9 ft. 6 in.

Span No. 4.

Distance, centre to centre of end pins,	57 ft. 6 in.
Number of panels,	6
Number of sub-panels,	12
Length of each panel,	9 ft. 7 in.
Length of each sub-panel,	4 ft. 9½ in.
Height of truss, centre to centre of chords,	5 ft. 9 in.
Distance, centre to centre of trusses,	26 ft. 6 in.

In the fourth span, the cross girders occur at every sub-panel.

Wrought Iron.—All the wrought iron must be of the best quality, tough and fibrous, free from flaws and cracks along the edges. All the iron in the tensile members, lower chords, tension laterals, diagonals, bolts, etc., etc., must be doubled rolled from the muck bar direct, no scrap will be allowed, and must be capable of sustaining an ultimate stress of sixty thousand (60,000) pounds per square inch, on a turned-down or grooved section, with no permanent set under twenty-five thousand (25,000) pounds per square inch. When tested to breaking, if so required by the Engineer, the links and rods must part through the body, and not at the pin hole in the head.

All workmanship must be first-class. All abutting surfaces must be planed or turned, so as to insure even bearings, and protected by white lead and tallow before shipment. No error of over one sixty-fourth ($\frac{1}{64}$) of an inch will be allowed in the lengths of bars between centres of pin holes, nor shall there be any variation in pins or pin holes of over one hundredth ($\frac{1}{100}$) the diameter of the pin; said holes to be accurately drilled. All riveted plates must come in close contact where abutting, and the rivet holes must be spaced accurately and truly opposite. Rivets must completely fill the holes and have full heads, and when necessary, they must be countersunk. Thickening washers are to be used whenever required to make the joints perfectly snug and tight.

Castings.—The cast iron work is to be true and sound, free from flaws and defects of any kind, and may be green sand castings, but should be of good tough iron, the lines sharp and clear and according to the drawings.

No rough or crooked castings will be accepted. All bolt and pin holes must be accurately drilled; all abutting surfaces must be planed, if necessary to insure even bearings and neat close fittings, and the castings are to be perfectly dressed and fitted up to make a good job generally, when put in the bridge.

General Conditions.—The whole of the construction to be in strict accordance with the drawings furnished by the Engineer of Bridges and Buildings of the Pennsylvania Railroad Company. In all cases figures are to be taken in preference to any measurement by scale. No alteration to be made unless authorized by the Engineer. All work to receive one coat of red lead in oil before being sent to the site.

Chemistry, Physics, Technology, etc.

ON THE LAWS OF ADHESION.

From Der Naturforscher, vol. viii, page 60. Translated by Cleveland Abbe.

Stefan has communicated to the Vienna Academy of Sciences a memoir on the nature and laws of adhesion, which is the result of elaborate investigations, and must be considered as of high value in this department of physical research. In giving a general account of his results, he says: "By apparent adhesion I intend to designate the phenomena that are shown when two plane surfaces, after being brought into contact, are separated from each other again by the direct application of force. This phenomenon has, thus far, been generally considered as the result of adhesion, that is to say, a result of the attraction of molecular forces between the neighboring portions of the two plates; and there have already been measurements made by others of these adhesive forces. In these cases there occurs no immediate contact of the two plates, but there lies between them a stratum of air of comparatively slight thickness. If, for instance, we choose for the experiment two glass plates, they will generally be found not to show the Newtonian color rings. These latter can, in fact, only be made to appear when we apply a very considerable pressure to the perfectly plane plates. If, therefore, in such a case, molecular forces are called into play between the two plates, it would follow that the so-called radius of molecular activity would have a magnitude far greater than is indicated by other classes of experiments. Still more remarkable will the phenomenon appear if we dip the two plates under water. We can, in this case, detect an apparent attraction between the plates when their distance is as great as one millimeter.

In order to obtain definite data, one of these plates was hung upon a balance, so that its lower surface was horizontal and in equilibrium. The second plate was under the first, and also horizontal; on it three pieces of wire were laid, and then the upper plate allowed to descend

until it rested upon these. The diameter of the wires determined the initial distance of the two plates. In order to separate the upper plate from the under, it was necessary to place a slight counterpoise in the opposite pan of the balance. From experiments of this kind it was found that this weight must be greater, the finer the wires that lie between the plates, and the larger the plates themselves. The weight of this counterpoise depended also upon the nature of the fluid in which the plates were dipped.

But the exact measurement of the weights necessary to raise the upper plate, leads, in repeated experiments under similar conditions, to many contradictory results; so that it seemed that the determination of the force necessary to separate the plates, had no physical meaning; that in fact in these phenomena we have to do not with a statical but with a dynamical problem. Almost any weight was found to be sufficient to raise the upper plate from the lower one, only the time in which this was accomplished was greater in proportion as the weight was less. That which it is important to measure, in this connection, is the continuous movement in which the upper plate is set, by the adding of a small counterpoise, and in consequence of which it immediately slowly separated itself from the lower plate.

This movement, at first, is an extremely slow one, the position of the index of the scale beam for a long time being apparently fixed, especially when the wires laying between the plates are fine, and the weight itself is small, but we can assure ourselves that the movement begins immediately that the weight is laid in the scale, by using appropriate optical aids. If, for example, we bring the plates so near to each other that by using mono-chromatic light we can observe the interference of the rays of light that pass between the plates, then immediately after laying a small weight in the scale beam, the interference bands slowly draw together, and soon become so fine as to be invisible; although one cannot notice the least movement of the index of the balance. Thus we understand how it happens that by confining our observations to a short interval of time, we have hitherto made the mistake of assuming that there existed for a moment a statical equilibrium. Now, however, that the dynamic character of the phenomenon is understood, it is no longer difficult, at least in general terms, to understand the various steps of the process, which are very nearly as follows:

Assuming the two plates to be, at first, at a given distance from each other, at rest, and the upper plate counter-balanced by a proper

weight. If we add then a small additional weight to the scale beam, at once the upper plate thereby receives an exceedingly small upward impulse, and the space between the two plates is increased. The fluid that is found within this space experiences a dilatation, and in consequence of this, there is a diminution of the hydrostatic pressure between the plates. If, however, the upper plate is pressed upward by the fluid underneath it, slightly less than before, still the pressure of the fluid above this plate remains the same, and a portion thereof remains uncompensated, which portion will therefore resist the upper movement due to the weight in the pan of the balance. Between these two forces, no equilibrium can be established, since the diminution of the hydrostatic pressure between the plates induces as a consequence, an inflow between the plates from the outer fluid under a permanently higher pressure; thereby the difference of pressure on the upper and lower sides of the upper plate is again diminished; the counterpoise again acts to elevate the upper plate, and the same operations are repeated over and over.

The force arising from the dilation of a fluid, and opposed to the draught of the counterpoise, has a greater effect, the more slowly the fluid flows from without into the space between the plates. The velocity of this flow is, for the same difference of pressure, smaller in proportion to the section of the current and the length of its path. Therefore, the velocity with which the plates separate from each other, will, under otherwise similar circumstances, be smaller in proportion as the two plates are nearer together, and of larger size. Furthermore, with the same difference of hydrostatic pressure, the velocity of the current will be smaller, the greater the viscosity or the interior friction of the fluid. Therefore, the velocity with which the plates separate from each other under otherwise similar circumstances is dependent upon the nature of the fluid in which the plates are immersed, and such a manner that the velocity is smaller the more viscous the fluid is.

For the exact determination of these relations, I have made a number of experiments in which I have confined myself to the observation of the time which the upper plate occupies in moving to a given distance from its initial distance from the under plate. The initial distance of the plates is given by the diameter of the three pieces of wire laid between them; the final distance is determined by means of a mark on the auxilliary arc of the balance, by means of

which the movement of the index is observed. The distance between these two positions was in all of my observations 0·26 of a centimeter. Some very simple relations between the data employed have been deduced from these observations. First, it resulted very plainly, both for the movement of the plates in liquids, and also in the air, that the time required to separate the two plates from the initial to the final distance, is inversely proportional to the weight of the counterpoise. Second, this time is for the same counterpoise greater, according as the original distance of the plates is smaller; it increases, *i. e.*, in a quadratic proportion, when the distance of the plates diminishes in simple proportion. Third, the time is furthermore greater, the larger the plates are that are used in the experiment, for pairs of plates, similar in all other respects, the times vary, as the fourth powers of the radii of the plates. Finally, as regards the influence and nature of the fluids; the experiments with water, solutions of salt, and with alcohol, and air, give coincident results, viz.: that the time in question is proportional to that occupied by equal volumes of these fluids flowing under the same pressure through a capillary tube. It is thus rendered evident that the phenomena in question, are problems in hydrodynamics, and the conclusion of Stefan's memoir, is an endeavor to devise a theoretical solution of these problems. These solutions are based upon the following considerations:

If a weight is laid in the pan of a balance which is otherwise in equilibrium, the force of gravity, during the sinking of the weight performs a work whose equivalent is found partly in the living force of the weight, but principally in that of the moving portions of the balance. In the present experiments, however, the movement of the balance is so exceedingly slow that its living force is very small in comparison with the work of gravity. The latter, therefore, must have its equivalent in some other work, and this is found in that work which is necessary in order to maintain the current of fluid flowing from without into the space inclosed between the plates. We have, then, to find an expression for this work, in order, by equating this with the work of gravity to be able to determine the motion of the plates. From the various conditions which the current must fulfill, it is possible to devise a formula for the velocity of the fluid at every point between the plates, which formula, if not perfectly accurate, still, must represent with great approximation the actual conditions. Based upon this formula, we can now calculate the work necessary to

be done, in order to maintain the current, and by equating this work with that of the sinking counterpoise, we obtain an equation from which we may determine the time occupied by the upper plate in order to move from one position to another, with respect to the lower plate. The actual formula found by Stefan, corresponds to all the various relations to which the experiments have led. This formula enables us, also, to compute from the experiments the coefficients of internal friction; and there results the coefficient 0·0108, as the coefficient for water at a temperature of 19°. For air, at the same temperature, we have 0·00183, which two numbers agree exactly with those that can be deduced from the experiments of Poiseuille, and with those that have already been determined by Maxwell and O. E. Meyer. This agreement between the results of the experiments and the theoretical development, could, however, only be arrived at under the assumption that the fluid is not perfectly quiet at the surfaces of the plates, but slides along these surfaces, while on the other hand, the experiments on the currents of fluids through capillary glass tubes lead to the presumption that the fluid immediately in contact with the sides of capillary tube has no movement. For the complete explanation of this difference between the results of different observations, there is still necessary a further series of experiments. The experiments in this present essay, resolve merely the particular question, viz.: as to the nature of the *apparent* adhesion, and thus enable us to give this phenomenon its right place in molecular physics.

Dangerous Explosive Mixture.—The Irish Court of Queen's Bench recently granted a motion to draw out of court a sum of £1500 tendered by the Governor and Directors of the Apothecaries Hall of Ireland, as compensation for the consequences of their mistake in selling a packet of sulphide of antimony for oxide of manganese.

A man named Marsden, intending to make oxygen, mixed chlorate of potash with the sulphide of antimony, instead of black oxide of manganese, and from the explosion which followed, he was killed, and his wife severely injured.

Chlorate of potash detonates with great violence when heated with sulphur or carbon, or with compounds containing these elements. Too much care cannot be exercised in making oxygen to be assured that the oxide of manganese used is free from contamination.

REPORT ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.†

(Continued from Vol. lxx, page 52.)

The air is driven by means of a blast, at a pressure of 3 to 4 c. m. of mercury through a sheet iron box filled with caustic lime, and then conducted into the retort from above. The temperature of the latter can be judged by means of an aperture, which can be closed with an iron stopper. The air gives off only about the half of its oxygen, so that, for 1 volume of oxygen, 10 volumes of air must be passed through, the residue escaping into the atmosphere.‡ In about five minutes the revivification of the reduced mass is completed, when the stream of air is cut off by means of a cock with a triple perforation, and a current of superheated steam is passed through for five minutes, whilst immediately afterwards the gas which issues below the grate is conducted into condensers. Here a fine descending rain of cold water frees the oxygen from steam, and it enters the gasometer under the pressure of a column of water of from 8 to 10 c. m. in height. In this manner, reduction and oxidation alternate at intervals of five minutes. Not until six hours have elapsed does it become necessary for a more complete revivification of the mass to pass atmospheric air over it for an hour, for in five to six hours the yield of oxygen sinks from its original quantity down to the half, or even the third. The cocks are set at Vienna by a self-acting movement. The longer watery vapor is introduced, and the retorts thus freed from atmospheric air before opening the communication with the gasometer, the purer is the oxygen. Half a minute suffices to bring down the nitrogen to 15 per cent., if the useless space in the retorts is kept as small as possible. If, as is easily practicable, the nitrogen is brought down

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

† From the *Chemical News*.

‡ Latterly, Tessié du Motay has attempted to convert the escaping nitrogen industrially, first into nitride of titanium, and then into ammonia.

to 4 per cent., there is a greater waste of oxygen. To be certain that the amount of nitrogen remains within the limits of from 10 to 15 per cent., samples are taken from the gasometer in graduated tubes, and the oxygen is absorbed by means of known quantities of potash and pyrogallic acid, a reaction which, even in inexperienced hands, gives quick and accurate results.

As any cooling of the retorts below a dark red heat diminishes the yield, care is taken to heat both the air and steam to about 300° C. At Pantin, where there are several groups of 10 retorts each, two of them are filled with pumice-stone, and serve for heating the air and the steam. The composition of the mass is 2 molecules of NaOH, 1 molecule of MnO_2, and the fifth of a molecule of oxide of copper, which merely serves to separate the other ingredients and render them more accessible to the influence of steam and air. At Comines, the black oxide of manganese is regenerated in the ordinary manner from chlorine residues, and is almost pure; its price is 2 francs per kilo. The great cost of this fundamental article is not of importance, since it can be used the longer, the more carefully the air is freed from carbonic acid. If, in consequence of some inevitable interruption of the process, the mass absorbs atmospheric carbonic acid, it is simply requisite to heat to redness, and to pass a current of steam over it till the escaping vapors cease to render lime water turbid. The temperature is then raised and air passed over the mass, when it regains its original efficacy. The average duration of a retort is one year.

Tessié du Motay's process yields oxygen at 90 per cent., at the cost of 15 to 30 centimes per cubic meter,* or, according to the experiments of Kuppelwieser, in Vienna,† 3 florins per 1000 cubic feet, a price which agrees with the former, and which scarcely exceeds that of coal-gas. We may regard this process as the final and successful solution of the problem as to the economical and rational production of oxygen.

We have still to review a group of projects, which, without any chemical agents, aim at extracting oxygen from the atmosphere by a purely mechanical procedure. They are based upon two physical principles, diffusion or absorption.

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* Phillips, "Der Sauerstoff," 18.

† Kuppelwieser, *Berg. und Hütten Ztg.*, 1873, 354.

Th. Graham, who, in his classical researches, investigated the laws of the escape of gases through narrow apertures, made known in 1866* that air which is drawn through a fine chink in a plate of caoutchouc, passes in the constant proportion of 41·6 per cent. of oxygen, to 58·4 per cent. of nitrogen, the half of the atmospheric nitrogen being held back. This mixture causes glowing chips of wood to burst into flame. Deville† tested the industrial value of this process, and found that the time required was too long.

Absorption has been utilized in two distinct forms. Montmagnon and De Laire in 1868 took out a French patent,‡ based upon the observation of Angus Smith,‖ that charcoal absorbs from the air more oxygen than nitrogen. According to them, 100 liters of wood-charcoal absorb 925 liters of oxygen, and only 750 liters of nitrogen. If moistened with water, they give off 350 liters of oxygen and 650 liters of nitrogen, so that 575 liters of oxygen and 55 (100 ?) liters of nitrogen remain and can be extracted with the air pump. By repeating this process with the same gaseous mixture, they succeeded in bringing the oxygen almost in a state of purity. Whether this process has ever been carried out on the large scale is not known. An attempt has, however, been made with Mallet's method,§ based on the property of water to absorb oxygen rather than nitrogen.

The coefficients of absorption of the two gases are 0·025 for N, and 0·046 for O. If multiplied by the proportion of their bulk in the atmosphere, 0·79 for N, and 0·21 for O, these numbers give the volume proportion of both gases in water = 0·0197 N and 0·0097 O; or, the air absorbed in water contains, in one volume, 0·67 N and 0·33 O. If the unabsorbed nitrogen is allowed to escape, and the absorbed gaseous mixture, richer in oxygen, is withdrawn from the water and again absorbed, it follows, from the multiplication of the two coefficients of absorption with the volume proportions of 0·67 N and 0·33 O, that the gaseous mixture now taken up has the composition 0·525 N : 0·475 O; a third absorption raises the result to 0·375 N : 0·625 O; a fourth to 0·25 N : 0·75 O; and a fifth to 0·15 N : 0·85 O, the proportion in

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* Graham, *Comptes Rendus*, lxiii, 471.

† Deville, Wagner, *Jahresberichte*, 1867, 216.

‡ *Bull. de la Soc. Chim.* [2], xi, 261.

‖ Angus Smith, *Proc. Roy. Soc.*, xii, 424.

§ Mallet, *Dingler's Polyt. Journ.*, cic, 112.

which the two gases occur in Tessié du Motay's oxygenous mixture. After the eighth absorption, the gas is almost pure oxygen (0·973 O and 0·027 N).

Mallet's apparatus consisted of a larger or smaller number of strong iron water holders, connected with each other by means of suction and forcing pumps. Into the first air is driven through fine apertures at a pressure of about five atmospheres. The unabsorbed nitrogen escapes by a valve. The absorbed gas is now extracted by the second pump from the first receiver, and forced into the second. With a series of four receivers the operation lasts five minutes. If the receivers serially decrease in size, the first holding 10 cubic meters, and the last 5, the result of a continuous working of the process is 7760 liters per hour of a gaseous mixture containing 75 per cent. of oxygen, or 168 cubic meters in twenty-four hours. The cost of working, wear and tear, and supervision, are said to be insignificant. Where motive power is cheap, *i. e.*, water-power or the waste heat of metallurgical processes, this method may consequently be applicable, especially for use in such metallurgical operations where a mixture comparatively poor in oxygen is serviceable.

If we sum up the results of our survey of the methods for the industrial prepartion of oxygen, we must place Tessié du Motay's process in the first line, as well tried and proved, and in the second, Mallet's mechanical process as just described.

Finally, we pass to the question: To what applications has oxygen hitherto been put? As the supporter of combustion, we owe to it heat and light; and, as the medium of respiration, it is the condition of life.

If we consider oxygen from these three points of view, its metallurgical applications first draw our attention. What it has already done for the platinum manufacture has been explained above. For the autogenous soldering of lead it has been dispensed with, since hydrogen or coal-gas burnt in atmospheric air gives out a sufficient heat; but the example of this art encourages us in connecting great hopes with the extended applications of oxygen. Says an esteemed practical metallurgist, Clemens Winkler:*—

"As gold, when used for soldering platinum vessels, impairs the

* Clemens Winkler, *Deutsche Industrie Blatter*, p. 182. *Zeitschrift d. Vereins Deutsch. Ingen.*, xvi, 714.

appearance, since the soldered places appear yellow, in the same manner the whiteness of soft solder is an eyesore when it is applied to colored metals. This evil induced the Prussian Association for the Promotion of Manufacturing Industry to offer a reward for the discovery of a yellow solder—a problem not easy to solve without the prior discovery of a new easily fusible metal of a red or yellow color.* It would be more useful to turn our attention to the autogenous soldering of metals with the aid of the oxy-hydrogen flame, a principle which has achieved such signal triumphs in the treatment of two essentially different metals. Should it not be possible, by the same means, to solder every metal and every alloy with itself, as tin with tin, copper with copper, brass with brass, silver with silver, gold with gold, and even iron with iron, just as we already solder lead with lead and platinum with platinum? The probability is present, and the advantages of such a procedure are manifest. Let us try to conceive the neatness of a workshop in which soldering is performed, not as heretofore, with the soldering-iron or at the forge, but with a light, elegant gas-burner. Imagine the artisan no longer annoyed by radiant heat and by the fumes of charcoal, and able to produce in a moment any temperature required, even the very highest, and again to put an end to it by simply turning a cock. Conceive the solidity of the soldering which no longer depends on cementing two pieces of metal with a foreign matter, but on an actual interfusion of two portions of one and the same metal, and which involves the utmost economy of materials and dispenses with all subsequent work, such as trimming the soldered place with a file. Such evident advantages must overcome every prejudice, and prompt us most urgently to commence a thorough experimental investigation of the question."

But also in the most extensive fields of metallurgy, the preparation of iron and steel, technologists of merit have pointed out the advantages to be derived from cheap oxygen.

Cameron† recommends the use of oxygen, or of air rich in oxygen, as obtained from Mallet's absorption cylinders, instead of ordinary air in blast-furnaces; and we may here remark that the absorption of oxygen in water has been already unintentionally used for this pur-

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* The offer has, therefore, been subsequently withdrawn.

† Cameron, *Berg. u. Hüttenm. Zeitung*, 1871, 132.

pose, although in a form capable of improvement. Br. Kerl* has called attention to the fact that the air from the water-blast is richer in oxygen than common air.

It has also been observed that old charcoal burns more energetically than recent, because the former has absorbed oxygen from the air, a circumstance which has been practically utilized with advantage in refining crude iron.†

Kuppelwieser recommends air rich in oxygen for treating white crude by the Bessemer process, and he is of opinion that the cost of Tessié du Motay's process would not require to be far reduced to render oxygen available for this purpose.‡ A great future appears open here for the utilization of oxygen. Nevertheless, Le Blanc's objection cannot be overlooked, that more infusible crucibles, furnaces, etc., would be required, the cost of which would render the advantage of the process doubtful.

Turning from metallurgy to the production of light, we must admit that, since 1826, when Drummond‖ invented his oxy-hydrogen light, and applied it for land-measuring and for lighthouses, no one can have questioned the value of oxygen for this purpose. As the price of the gas was reduced, its application was extended, an example being especially set in America. H. Vogel,§ in the year 1870, found oxygen in successful use at New York, not merely for lighthouses, signals, and the building of houses, but also for aquatic structures and for several applications of the magic lantern. The aquatic operation in connection with the great Brooklyn Bridge over the East river, then in course of erection, was lit up with twelve oxy-hydrogen lamps, which consumed daily 2000 cubic feet of oxygen.** Instead of lime points, the more permanent zircon cones were used, with great advantage. In Paris, also, the Théâtre de la Gaité and the Alcazar were illuminated with a fairy splendor.

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* Br. Kerl, *Grundriss der Hüttenkunde*, i, 217.

† *Journ. Prakt. Chemie*, ci, 397. *Bergwerksfreund*, iii, 513.

‡ Kuppelwieser, *Berg. u. Hüttenm. Zeitung*, 1873, 354.

‖ Drummond, "On the Means of Facilitating the Observation of Distant Stations in Geodetical Operations."—*Phil. Trans.*, 1826.

§ Vogel, *Ber. Chem. Gesell.*, iii, 901.

** Vogel says, by mistake, cubic meters.

At the Opera House at New York,* a diagram of about 10 square meters upon a screen of damp muslin was lit up by the aid of a system of powerful lenses, whilst the lamp stood at the back-ground of the stage at the distance of 25 meters, and gave a striking effect. In conjunction with this light, the magic lantern was adopted in America to exhibit apparatus, photographs on glass, and other drawings in large lecture halls, especially since Outerbridge discovered the way of using thin plates of gelatine for the production of lithographs or pen-drawings. The effect is easily conceived if we remember that the oxy-hydrogen flame is 16½ times more brilliant than that of an ordinary burner fed with the same amount of gas.

The daily production of the New York Oxygen Company amounted in 1870 to 30,000 cubic feet, or 850 cubic meters. The gas is delivered in iron cylinders (Robert Grant's patent, New York), 9 inches in diameter and 30 inches long, which are filled with oxygen under a pressure of 20 to 30 atmospheres. The cylinder is sold at 1 dollar per cubic foot, including the oxygen contained in it at ordinary atmospheric pressure. The oxygen, on refilling, is supplied at five cents per cubic foot under the pressure of 1 atmosphere,† an exceedingly high price, more than twenty-two times as great as Kuppelwieser's calculation, as quoted above, although Tessié du Motay's method is in use in New York.

Since 1867, Tessié du Motay has attempted to apply the oxygen light to streets and squares. The places before the Tuileries and before the Hotel de Ville were radiant with the light thrown off by cylinders of zircon‡ under the joint influence of coal-gas and oxygen. The fluctuating nature of the flame and the great expense induced him to turn his attention to the carburation of hydrogen and coal-gas. These gases were led before entering the burners into a vessel attached to each lamp, and containing heavy hydro-carbons. In this manner the Boulevards, between Rue Drouot and Rue Scribe, were illuminated with 70 oxygen burners. This method, also, was given up, and a highly carburetted gas was prepared in place of common coal-gas, and was burnt along with oxygen. In this new modification, the process

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* Morton, *Journal of the Franklin Institute*, liii, liv, lv.

† *Deutsche Gewerbe Zeitung*, 1867, p. 18.

‡ Burnt zirconia kneaded into a paste with aqueous boracic acid, and burnt in iron moulds at a red heat.

was seen by visitors to the Vienna Exhibition at the Empress Elizabeth Western Railway Terminus. From a manuscript report, which Herr Karl Haase, manager of the 4th Berlin gas works, handed in to the directors of the municipal committee on lighting, we borrow the following graphic description:—

"The sight of the plantations of the Elizabeth Station, and of its various compartments lit up with coal-gas and oxygen, is quite surprising. The effect of the light given off by the small bluish flames of the lamps is quite peculiar, and cannot be paralleled by any other system of lighting. The green of the trees and shrubs appears more lively, the color of costumes more brilliant, and above all, the faces of persons seem more distinct. Every shade of color and every configuration comes out almost as distinctly as in full daylight, and yet the eye is not wearied. This favorable impression received in the plantations is still heightened on entering the large second-class waiting room. Here every object, and even the most trifling details of the decorations, are shown most distinctly by the small flames of two moderate-sized gasoliers.

"The strongest impression as regards the efficacy of this new system of illumination is experienced on entering the departure platform. Here, in order to make the difference more striking, the stairs used by the departing passengers were lit up with heavy gas aided by oxygen, but only half as many lamps were kindled, as on the opposite stairs, where the old gas was burning along with oxygen. In spite of the double number of the burners and the good quality of the coal-gas (equal 24 candles), the space lighted on the new system appeared far more brilliant."

In spite of this favorable impression, however, Haase declares the new double gas, which is conveyed in two sets of pipes, unsuitable for general private consumption. He gives, amongst others, the following reasons for his opinion: The advantage of brightness is more than compensated by the price, which in Berlin, calculated for the same degree of brightness, would amount to double the price of common gas.

The consumer will not be able to manage accurately the changing regulation of the cocks. The oxygen will become impoverished by passing through long distances of mains, and the repairs of the double system will be considerable, etc. For certain public establishments, for millinery warehouses, and certain other purposes, the new process will be well adapted. But it would be out of the question to keep up

a triple system of mains for the sake of such limited applications. This opinion is in flat contradiction to that of Schiele;* but it agrees closely with the report which Le Blanc† a year earlier had presented to the municipal gas direction of Paris.

(To be continued.)

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF VASSAR COLLEGE. NO. 1.—ON THE THEORY OF THE THERMOSCOPE.‡

By LEROY C. COOLEY.

At a meeting of the Albany Institute, in April 1873, a paper was read describing an instrument by which to detect very slight variations of temperature by the swinging of a needle, caused, as was then stated, by delicate air-currents. In November, of the same year, this *thermoscope* was described in this JOURNAL, and its applications in the lecture room illustrated. A description of the instrument in still more perfect form, with experiments showing the exceeding delicacy of its action, followed in June, 1874, and since then experiments amounting, in the aggregate, to several hundreds, have been made at intervals when the pressure of other work would allow. In the meantime, the experiments of others, supremely those beautiful ones by Mr. Crookes, described at a late meeting of the Royal Society in London, have called in question the cause of the needle's motion, and made the theory of this class of instruments a more important subject of discussion than are any of its possible applications. Passing, for the present, therefore, experiments suggesting applications of the instrument which, it seems to me, cannot fail, in the end, to be interesting and valuable, the purpose of this paper shall be to present considerations bearing upon the theory of its action.

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* *Schiele, Journal f. Gasbeleuchtung*, Jan., 1873.

† "Rapport de M. F. Le Blanc sur le nouvel éclairage oxy-hydrique. Paris, 1872; also, *Journal f. Gasbeleuchtung*, 1872, 641.

‡ Read before the Poughkeepsie Society of Natural Science, July 26, 1875.

I.

The essential fact may be briefly stated. It is this: a needle, long and light, delicately suspended horizontally in a chamber, such as to protect it from other external influences, will be put in motion by very slight differences in temperature.

Fig. 1.

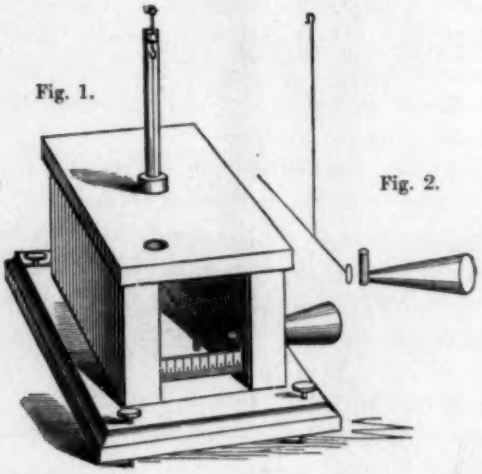

Fig. 2.

In the apparatus now in use, (Fig. 1) the needle consists of a glass tube, twelve inches in length and so slender, that with the disk of paper, which it carries upon one end, and the cement necessary to unite them, the weight is a little less than two grains. This needle is suspended in a horizontal position by two single fibers of silk, eighteen inches in length, parallel, and one-fourth of an inch apart, protected by a glass tube rising from the top of the chamber for this purpose. The chamber is a double-walled box, eighteen inches long. The inside walls are glass; the outside walls are wood, except at the ends, where are thick plate glass windows, through which the motions of the needle may be observed. The space between the walls being of considerable thickness is, except at the ends, filled with cotton wool. Through one side of the chamber, and just opposite the disk of the needle, the small end of a conical reflector projects into the interior. A piece of *scorched paper* covers and completely closes this end of the cone and receives the radiations from any distant source collected and thrown upon it by the reflector. Through

the top of the chamber is an opening which allows the insertion of any object whose thermal condition is to be directly tested, while, finally, a scale for measurement, graduated upon glass and placed in front of the disk marks the direction and amount of the deflection suffered by the needle.

So sensitive is this instrument to changes of temperature that when a person sits several feet away in front of the conical reflector, the needle will move, perceptibly toward the charred paper, by the heat radiated from his face. And when a copper wire, having been struck by a small hammer falling a distance of ten inches, is thrust into the chamber, the needle swings toward it to announce the rise of temperature occasioned by the blow.

By diminishing the distance between the parallel filaments of suspension, the sensibility of the instrument is increased, and when the suspension is by a single fiber, the needle has been known to move perceptibly in obedience to the heat of the face at a distance of thirty feet. But this exceeding delicacy has its disadvantages. No quantitative results can be easily obtained with it because the torsion of the fiber is not sufficient to bring the needle back to its zero. On the other hand, the suspension by parallel fibers is sensitive enough for most purposes and secures a tolerably sure and quick return of the needle after deflection.

II.

But by what influences are heat and cold able to demand these motions? We know that air is put in motion by changes of temperature—that it moves toward and upward from a source of heat, downward and away from a centre of cold, and hence the principle of convection is the one nearest at hand to explain the deflections of our needle. On the other hand, it seems almost incredible that currents of sufficient power should be invariably produced by changes of temperature so exceeding slight. Is there a possibility of deciding whether the movements are due to something in the nature of air currents, or to a more direct attraction or repulsion by the source of heat or cold?

Two methods of investigation are available, *first:* if the motion of the needle, *under all circumstances*, should prove to be *exactly what air currents would produce*, we may justly infer that it is due to convection. Or, *second:* if the motion *should cease to occur when the*

air is completely removed we are warranted in the belief that it is due to the same cause.

Considering the fact that this second line of thought was chosen by Mr. Crookes and wrought out by him with such charming results, I cannot help thinking myself fortunate in having selected the first. It will be seen that my experiments have to do altogether with the motion of the needle *in air*, while in the sequel, we shall notice that his were extended to the motion occurring in vacuo, and perhaps discover the meaning of apparently conflicting results.

III.

We set out then to determine whether the motion of the needle is, in all cases, such as the principle of convection is competent to explain. The needle may be under the direct influence of a body with a different temperature, in its own immediate neighborhood, or under the less direct influence of a body radiating its heat from a distance; let us examine the second of these cases first.

In the earlier experiments, a disk of the thinnest kind of glass closed the inner end of the conical reflector, and received radiations from a luminous flame of an oil lamp placed at a distance. Afterward the scorched paper was substituted for the transparent glass, with no other variation in result, than a perceptible increase in the sensibility of the instrument. Considering the opacity of the carbonized paper to all forms of radiation, we might infer that *the needle is not moved by the energy transmitted*, but rather by that which is absorbed. Again, during the transition from the use of glass to that of paper, the reflector was left without either. In this case the thermal and luminous energy of the distant lamp flame was collected by the reflector and converged directly upon the disk of the needle. It was a case in which all other possible influences would seem to have the most perfect freedom of action, but one in which no air currents would be set up. The needle *refused to make any perceptible response* whatever. Passing these preliminary, but suggestive indications, we enter upon the more direct line of present thought.

When the flame of an alcohol lamp was placed at a distance of two feet away in front of the conical reflector, the needle, whose disk was a trifle below the level of the cone, after a few seconds, invariably moved toward the carbonized paper, while if a block of ice

were substituted for the flame, the needle recognized the change by invariably moving in the opposite direction.

Now, if, again, we remember the athermic character of carbon, we must admit that the carbonized paper warmed by the flame and cooled by the ice became itself the immediate source of influence under which the needle moved, and that the motion was exactly that which air currents would be competent to produce. But it may be said that the paper becomes itself the centre of radiation as well as of warmth and that, therefore, some other force may at least take part in producing, if indeed it to be not the sole cause of the motion. Another series of experiments would seem to bear upon this point, since the arrangement was such as would seem to shield the needle disk from any possible influence radiated from the paper and yet allow freedom to the action of any possible air currents set in motion by its contact.

The carbonized paper was inserted through one side of a short tube of thick card-board, (Fig. 2.) The tube was somewhat flattened and its lower end was one-half an inch below, while the upper end was twice that distance above the end of the cone by which it was pierced. The needle was then lowered until its disk was on a level with the lower end of this chimney and about an inch away. Whenever the alcohol flame was placed at a distance of two feet in front of the reflector, the needle very promptly moved toward the mouth of the chimney; but when, the flame away, and the needle at zero, a block of ice was substituted, the needle announced the change by moving away.

Again, when the needle was lifted to a level with the top of the chimney, opposite effects were witnessed; it moved very slowly, but very surely, away when the paper was warmed by the flame, and approached when it was cooled by the ice. We need scarcely stop to say that these motions are exactly what a gentle air current would produce when set in motion upward through the tube by a rise of temperature, or downward by a loss of heat within.

But another experiment in this series is still more significant. The lamp flame having been stationed at a distance of six inches instead of two feet away, the needle when brought to a level with the mouth of the chimney swung toward it more promptly and more rapidly in obedience to the intenser heat, but when carried to a level with the top of the chimney and when under the influence of the same intenser heat, the needle swung with considerable alacrity in

the same direction, toward the tube. These results were not accidental; they were invariably the same. But why should the gentler and the intenser heats of the flame at two feet and at six inches produce opposite effects?

A homely experiment may illustrate the well-known principle in accordance with which this change in the direction of motion is effected by the intenser heat. Let a pith ball, suspended by a silk fiber, hang near to and upon a level with the upper end of a vertical tube. Just above the end of the tube fix, horizontally, a small card-board cover. Then let a current of air be blown, with some considerable force, up through the tube. The outflowing current will carry the pith ball away. But remove the cover from above the tube, and the ball will be drawn toward the current, until brought into and carried upward by the stream. Now the motions of our needle seem to be a beautiful illustration of a delicate action of the same principle. When the heat is *very* gentle, the current is very weak, and, compelled to force its way upward against the resistance of the superincumbent air, it spreads outward on reaching the top of the chimney and carries the needle-disk away with it. But by intenser heat, a stronger current is produced, one which, able to lift the air above, continues its upward motion, and, the adjacent air, wafting the needle with it, moves toward the current.

By still another series of experiments, the evidence in favor of conviction is strengthened. Screens of various kinds were placed between the carbonized paper and the needle-disk and the time required to put the needle in perceptible motion noted when the alcohol flame was two feet away.

When the screen was made of common card-board the approach of the needle began in a time varying between 13 and 16 seconds, eight experiments yielding an average of $14\frac{3}{4}$. When the screen was of the same material, but of double thickness, the approach began in from 13 to 16 seconds, an average of the same number of experiments being 15. When the screen was one thickness of card-board covered with gilt paper, and this good reflecting surface toward the cone, the approach began between the same limits of time and eight experiments gave an average of $14\frac{1}{2}$. When the screen was glass, the average was $15\frac{1}{8}$, and when it consisted of card-board, gilt paper and glass, all three thicknesses in one, the times of approach were between the same limits, nor did a metallic screen or various others,

supposed to be athermic in a high degree give any essential variation.

The force which moves the needle, therefore, does not vary with the thickness, nor the nature, nor the condition of the surface of the screen interposed. Now convection currents would not be altered by any change in these characters of the screen, but all other influences, except indeed, such as would be in the nature of gravitation, vary in intensity with the varying thickness, or nature, or condition of the substance through which they are compelled to act. This unvarying effect—motion of the needle, must be attributed to the unvarying cause—convection currents.

Again, the conditions were changed. A body employed as the source of heat or cold was brought into the immediate vicinity of the needle by thrusting it through the opening in the top of the chamber. When the body, of whatever character, was warmed by any means, whether by a blow, by friction, by contact with the fingers or face, or by a lamp flame, the needle moved toward it with a promptness and speed, and to a certain distance depending on the intensity of the heat. Not so invariable, however, were the effects of a reduced temperature.

A copper wire, about one-tenth of an inch in diameter, was insulated from the touch of the warm fingers by passing through a cork, which also served to support it by resting on the top of the chamber, when it was inserted through the opening. A test tube was fixed erect in a vessel of ice water, and the wire was cooled at will by a plunge of longer or shorter duration into the cold air within this tube.

The wire having been cooled by brief immersion in this cold air bath was thrust into the chamber, its end being about an inch over the needle-disk. The needle moved rapidly away a few degrees, oscillated a little, and then slowly returned, the natural effect of a gentle downflow of cooled air from the wire above. But when the wire was lengthened to reach down to a point below the level of the disk and cooled again, the needle sprung with surprising quickness *toward* it. Repeating the experiments only reproduced the same results, until, the wire, in one case, having been cooled by a briefer insertion in the cold air, the monotony was broken; the needle first moved away, then returning passed its zero toward the wire. These results were invariable.

To give greater precision to these experiments, the time of cooling the wire was noted, and in the first place, made just ten seconds. The following results were obtained in the first five experiments. The scale reads both ways from zero; let the + sign indicate motion away from, and the — sign motion toward the wire:

Ex. 1, . .	$+\frac{3}{4}°$ . .	$-\frac{1}{2}°$ . .	$+2°$ . . 0.
" 2, . .	$+\frac{1}{2}°$ . .	$-\frac{3}{8}°$ . .	$+2°$ . . 0.
" 3, . .	$+\frac{1}{2}°$ . .	$-\frac{3}{8}°$ . .	$+2°$ . . 0.
" 4, . .	$+\frac{5}{8}°$ . .	$-\frac{1}{2}°$ . .	$+2°$ . . 0.
" 5, . .	$+\frac{1}{2}°$ . .	$-\frac{3}{8}°$ . .	$+2°$ . . 0.

The uniformity of this oscillatory motion was curious and interesting. But in the meantime I had discovered that it was exceeding difficult to introduce or withdraw the wire without, by this act alone, disturbing the needle. To avoid this source of error, I inserted a tube, closed at the bottom, made of letter paper and carefully scorched. By inserting the cold wire within it, the walls of this tube would be cooled, and the stationary paper would thus become the body to disturb the needle. As would be expected, it required a longer immersion of the wire in the cold air, to enable it to cool the paper to produce the same effect, but by inserting it after immersion of 40 seconds, a repetition of the preceding experiments gave essentially the same results. There was the same oscillatory motion with a similar degree of uniformity. Why should the motion of the needle possess these characteristics? Are there air currents alternating in direction? Or have we a veritable attractive and repulsive action? Or is there a struggle between convection currents and attraction or repulsion? For a time the phenomenon was a puzzle.

I was not long, however, in learning that the oscillatory character of the motion was affected by varying the degree of cold employed. With a certain degree less than before, the negative values of the above table were reduced to zero, the others remaining essentially the same, and in response to a degree still less, this second column was altogether eliminated, that is to say, the needle, once started away, continued, without halt, to the far limit of its swing, returning to zero only when equilibrium of temperature was restored. On the other hand, by increasing the degree of cold, a point was reached at which, the values in the first column disappeared, while those in

the second were increased. By further increase of cold, the third column began to vanish, and, with sufficient intensity, the table was reduced to a single column, the second, in which the values were largely augmented. In other words, the motion of the needle was altogether toward the cooled paper, returning only with the return of equilibrium of temperature.

Thus it appears that the oscillatory character of the motion is abolished by employing different degrees of cold. With very slight reduction of temperature, the needle invariably recedes, but a very considerable reduction always demands approach. Is convection competent to explain this action?

A gentle cold would produce a very slight disturbance of the air. A very gentle current downward will press the air in its pathway outward and expend its force in so doing. It is by this action that the recession of the needle is produced. An intenser cold must produce greater disturbance. The downflow of air, sufficiently cooled, constitutes a continuous stream by which the adjacent air is drawn along, according to the principle already illustrated, by the homely pith ball experiments, and the inflow of air thus occasioned compels the needle with it toward the stream. With a degree of cold between these two extremes, an oscillatory motion is inevitable.

But this oscillatory motion, so like the effects of attraction and repulsion, was abolished in another way. In order to concentrate the influence which disturbs the needle, a ball of anthracite, one-fourth inch in diameter, suspended by a silk thread, was substituted for the long wire. By varying the length of the thread, the ball was held at any desired point in the tube. Placing it an inch above the level of the needle, the motion was *away* from the tube. Placing it an inch below, the motion of the needle was in the opposite direction. Not only was the oscillatory character of the motion abolished by thus concentrating the influence which caused it, but it was also found that the *direction* of the movement was changed by simply changing the place of its action.

The meaning of these results is unmistakable. The direction of the motion *ought* to change with the change in the position of the cold body, if it be due to air currents, but who can suggest an influence not in the nature of convection whose action would be thus inverted?

IV.

I come now to consider another part of my subject. If the movements of the needle be, as the foregoing experiments seem to prove, caused by convection in air then, *a priori*, they would be diminished by withdrawing the air, and would cease altogether if the vacuum should become perfect. Thanks to the skill of Mr. Crookes, this experiment seems to have been made in the most unexceptionable manner. By ingeniously constructed apparatus, he has been able to subject light bodies of various kinds to the action of radiant heat and light, in vacuo, varying in perfection up to a degree which has perhaps never before been obtained. He finds that the motion of the needle toward a source of heat grows less as the exhaustion proceeds and ceases when a certain perfection of vacuum is reached. Up to this point his experiments seem to afford a complete verification of the convection theory. Science owes him renown for going further and unmasking the delicate force of "repulsion by radiation," which, to be able to make its existence known, awaited the help of his genius to overcome the overwhelming force that opposed it. In air, the motion is toward the source of heat; in a vacuum beyond a certain very high degree of perfection it is, as Mr. Crookes has shown, away from the source of radiation. I think I may claim that my experiments show that the cause of motion *in air* is altogether in the nature of convection, and *per contra*, not at all in the nature of a true attraction. On the other hand, they do maintain the profoundest silence on the question whether there may not be, at the same time, some other feeble and opposing forces acting. Let us admit the existence of such a force. Then in air it is altogether masked by the more powerful force of convective currents. By exhausting the air, the influence of convection becomes weaker and weaker; the power which drives the needle toward the source of heat, would, by reduction, gradually approach equality with that which had all the time been struggling to drive it away. Clearly there must be a certain degree of rarefaction beyond and in which the motion of the needle would "turn the other way." This is the "neutral point." Down to this degree of exhaustion the motion of the needle *toward* the source of heat is due to convection currents. Beyond this degree, the motion of the needle *away* from the source of radiation is due to